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Telephones: Their Construction, Installation, Wiring, Operation, and Maintenance.

A Practical Reference Book and Guide for Electricians, Wiremen, Engineers, Contractors, Architects, and others interested in Standard Telephone Practice.

BY

W. H. RADCLIFFE, E.E.,

AND

H. C. CUSHING, Jr., E.E.,

Author of "Standard Wiring for Electric Light and Power."

Containing One Hundred and Twenty-Five Illustrations, Showing Apparatus, Circuits, and Systems.

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PREFACE

THIS book in no way conflicts with the purposes of other publications on telephony, either of encyclopedic character or of less pretentious scope. It is intended for the amateur, the wireman, or the engineer who desires to establish a means of telephonic communication between the rooms of his home, office, or shop; between his house and shop; between his home and the homes of his friends; or between his shop and some distant building. It is also for the contractor who desires to do this work for others, or who wishes to build a small exchange in factories, mills, or small towns.

The reader is assumed to know absolutely nothing of telephony, and no intricate mathematics are used nor is mention made of any apparatus, circuits, or systems which are not thoroughly illustrated and described with respect to their construction, installation, wiring, operation and maintenance.

The equipments and the methods of wiring presented have been selected with great care from

those which have been in use for a sufficient length of time by the Bell and Independent companies to have proved their practical value and become thoroughly standardized. No partiality is shown the equipments and methods of either organization, except in so far as they are superior electrically, magnetically, or mechanically, or in illustrating the points to be impressed upon the reader.

THE AUTHORS.

JANUARY, 1908.

INTRODUCTION

Telephone Engineering, although one of the youngest of the engineering professions, and perhaps the most handicapped at the start, stands to-day among those most active and advanced. Starting with a simple invention of Prof. Alexander Graham Bell in 1876, the history of the telephone extends over a period of only thirty-two years. For several years after its birth, the telephone was looked upon as a mere toy, and, until the patents covering its important parts were bought by a corporation and a working system established, none realized the great future in store for it.

Telephone Companies operating up to the year 1895 were each a part of the corporation just mentioned, and known as the Bell Telephone Company. Upon the expiration in 1895 of the original patents governing the construction of the telephone, its essential features became public property, and many companies independent of the original one were formed to manufacture,

sell, and operate telephone apparatus. The Bell Telephone Company, however, continued to operate as before, and the organizations conducted irrespective of or in opposition to them, became known as Independent Companies.

The Development of the Telephone Industry during the last dozen years has been most remarkable, and is largely due to the competition between the Bell and Independent companies. Each year has witnessed improved apparatus, more efficient and less expensive service, with the result that the number of telephone subscribers has increased from 281,700 in 1895, the date of the expiration of the original patents, to approximately 7,000,000. The 7,000,000 telephones are about equally divided between the Bell and Independent organizations, the former of whom do most of their business in our large cities and towns, while the latter have exerted their efforts chiefly in developing trade in villages and smaller cities throughout the United States.

CONSTRUCTION, OPERATION, AND INSTALLATION OF TELEPHONE INSTRUMENTS

The Receiver.—The receiver in use to-day differs but slightly from the original magnet telephone brought out in 1876. Its principle of operation is precisely the same, and in explaining its action reference will be made to the simple device

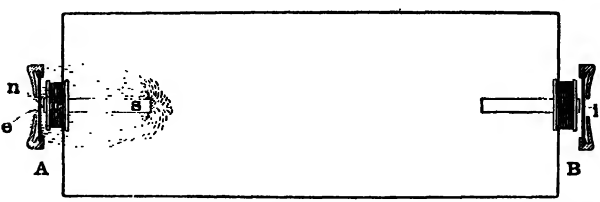


FIG. 1.—Simplest Form of Telephone Circuit, Showing Principles of Operation

at first employed. Fig. 1 shows one of these magnet telephones at *A*. The principal parts are: a permanent bar magnet *ns*, a coil of insulated wire *c* mounted on one end of *ns*, and a thin iron diaphragm or disk *e* supported in front of the magnet.

The Principle of the Magnet Telephone is as fol-

lows: The iron bar *n s*, being a magnet, is assumed to have lines of magnetic force issuing from one end and curving backward, entering the opposite end as indicated by the dotted lines in Fig. 1. *The magnetic circuits thus formed are completed* through the iron bar. On account of the iron diaphragm *e* in the path of these lines of force offering less resistance to them than the surrounding air, many lines will traverse the diaphragm in completing their circuits outside the magnet. If, now, the diaphragm be vibrated slightly to and from the end of the magnet, there will be produced a change in the lines of force; when the diaphragm is near the bar there will be a greater number of magnetic lines passing through the bar, because the resistance of the magnetic circuits has been decreased by shortening the paths of the lines of force, and when the diaphragm is not so near there will be less lines passing through the bar. The change in the magnetic condition of *n s* induces a varying electromotive force or electrical pressure in the coil of wire *c*.

Suppose, now, the magnet telephone just considered be connected to an exactly similar telephone *B*, by joining the terminals of the coils *c* and *r* together as in Fig. 1. The variation in the electromotive force produced in the coil *c* will now cause a varying current of electricity in the coil *r* of telephone *B*, and this in turn will cause a varying attraction of the diaphragm *i*, making it vibrate in unison with the diaphragm *e* of tele-

phone *A*. If, therefore, a person talks against the diaphragm *c* so that the sound waves of his voice cause it to vibrate, the diaphragm *i* will also vibrate in the same manner; and as the conditions at *B* are simply those at *A* reversed, the vibration of the diaphragm *i* will reproduce at *B* the sounds delivered at *A*.

In the transmission of speech, the telephone instrument into which the sound waves of the voice are delivered is called the transmitter, and that in which the sound waves are reproduced is called the receiver. In the description just given of Fig. 1, the telephone *A* has been referred to as the transmitter, and the telephone *B* as the receiver. Both these instruments in Fig. 1 are constructed alike, so it makes no difference in that case which one is used as the transmitter and which one as the receiver. In practice, however, the receiver alone follows the design of the magnet telephones in Fig. 1, the transmitter being constructed differently in order to increase the range of transmission.

Different Forms of Receivers are used to meet different conditions of service. The original single-pole receiver, of which those shown in Fig. 1 are a type, is still used for ordinary work over short distances. A commercial receiver of this form is shown in Fig. 2, *A* showing the case and interior construction with a side view of the magnet, and *B* an end view of the magnet. The magnet is formed of four pieces *c*, *e*, *r*, *n*, of hard magnet-

ized steel, two of which are placed on each side of the flattened iron end projections *u* and *v*, and all are bolted together at each end. The end projections *h* and *l* are of cylindrical shape and serve, the one for holding a wooden or fiber spool which carries the coil of insulated wire *s*, and the

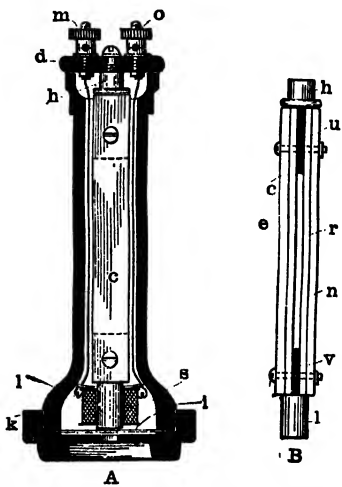


FIG. 2.—Single-Pole Receiver and Details of the Magnet Used in It

other for mounting the magnet to the surrounding hard-rubber case *d*. The coil *s* is usually wound with No. 38 B. & S. gage silk-covered copper wire to a resistance of 75 ohms, and its terminals are connected to the binding posts *m* and *o* by No. 18 or 20 B. & S. gage cotton-covered copper wire which is soldered to them. The magnet should have sufficient power to hold a weight

of 16 ounces. The diaphragm *i* is of soft iron 0.01 inch thick, is perfectly flat, and is held 1-32 inch distant from the end of the magnet by means of the hard-rubber cap *k*.

The Double-Pole Receiver for several years past has been gradually replacing the single pole receiver on account of its greater sensitiveness, and is now used entirely in long-distance transmission. Fig. 3 shows a standard receiver of this form. As its name implies, the magnet has two poles presented to the diaphragm; it is of horseshoe shape, the pole tips *s* and *s* being bolted to the legs *n* and *n* of the magnet and carry the coils *o* and *o*, which are mounted upon brass spools. The coils are con-

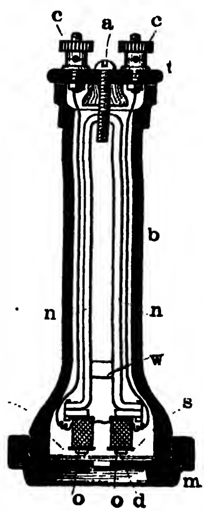


Fig. 3.—The Double-Pole Receiver

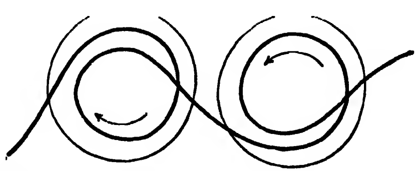


Fig. 4.—Method of Winding the Magnets for a Double-Pole Receiver

nected in series and are wound in opposite directions as in Fig. 4, with No. 36 or 38 B. & S.

gage silk-covered copper wire to a resistance depending upon the conditions of service. For local battery work, such as considered in this book, the resistance of the receiver is usually from 100 to 125 ohms (see Appendix) divided equally between the two coils. Cotton-covered copper wires are soldered to and connect the magnet windings with the inner parts of the binding posts *c* and *c*. The diaphragm is of ferrotype metal (a species of soft iron) No. 31 B. W. G., 0.01 inch thick, 2¼ inches in diameter over all, with a free diameter of about 2 inches, and a diameter of about ½ inch exposed to the sound waves. It is perfectly flat, and is varnished as a protection from corrosion. The magnet is turned upon the screw *a*, which holds it to the case, until the pole faces are $\frac{1}{32}$ inch distant from the diaphragm *d*. If there be a greater distance than this, the magnetic effect will be too weak, and, if less, the diaphragm is liable to stick to the pole faces. The magnet should be capable of exerting a tractive effort of 1.13 pounds. Between the legs of the magnet a lead weight *w* is cast to increase the weight of the receiver and thus insure its holding down the hook switch in its proper position.

The inclosing case is of hard rubber and comprises three parts: the body *b*, the tailpiece *t*, and the diaphragm cap *m*. Although the cap *m* can be unscrewed, permitting the diaphragm to be taken out and examined, it is impossible to take the receiver further apart without unsolder-

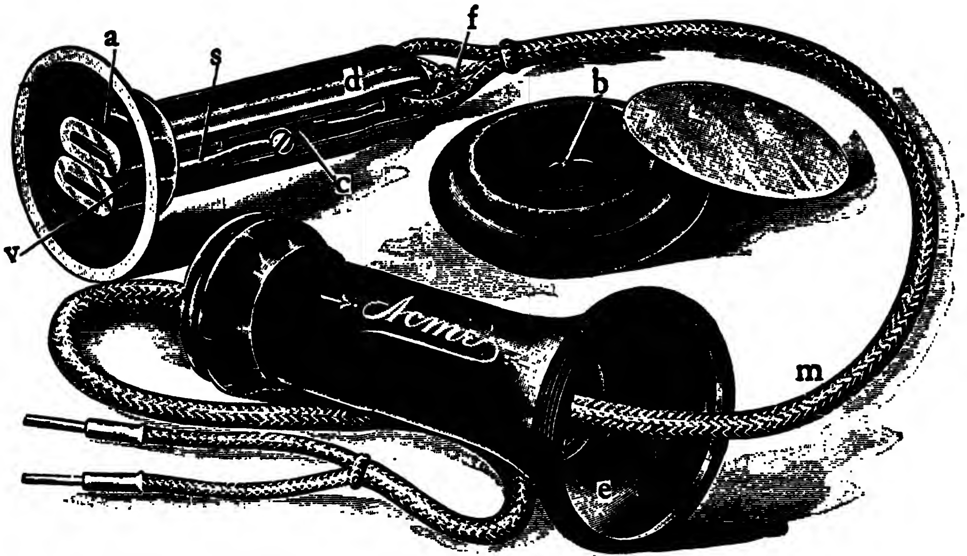


FIG. 5.—A Double-Pole Receiver with Interior Binding Posts for the Receiver Cord

ing the electrical connections between the leading-in wires and the magnet windings. In this respect the Acme double-pole, or bipolar, receiver shown in Fig. 5 differs, it being possible to examine all of the interior parts of this receiver by simply unscrewing the diaphragm cap and withdrawing the magnet from the body of the case. It will be noticed the receiver cord *m* is led through the case *e*, and the cord tips are secured to binding posts between the magnets. One of the binding posts is shown at *c*, and at *s* is one of the wires leading to the magnet coils *a* and *v*. Strain on the connections is prevented by the extra cord *f*, tied around the bend in the magnet bar *d*. Attention is also called to the small perforations *b* in the diaphragm cap, instead of an unobstructed opening, the object being to afford more ample protection to the diaphragm from pencils, etc., which are sometimes maliciously used to bend it out of shape.

The Head Receiver is a simple modification of the bipolar hand receiver. It is designed chiefly for switchboard operators and others who have almost constant use for a receiver or who desire the free use of both hands while listening. As seen from the head receiver shown in Fig. 6, it is very small and light, and is provided with a band *b* of spring steel covered with leather which fits over the head and holds the receiver against the ear. Fig. 7 shows the interior construction, which differs from other receivers only in that the body of the instrument, and therefore the magnet, are

shorter. The case is usually of brass or aluminum, and, being about the size of a watch, these instruments are often called "watch-case" receiv-

FIG. 6.—The Head Receiver

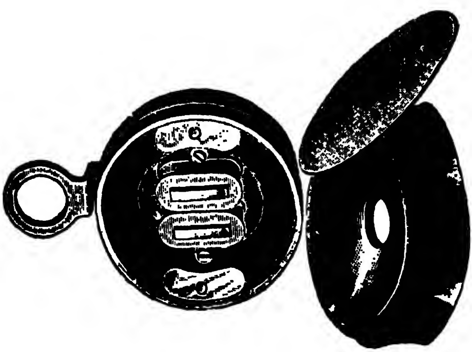


FIG. 7.—A View of the Interior of a Watch-Case or Head Receiver

ers. Their entire weight is generally not over six ounces.

The Transmitter.—The magnet telephone as a transmitting instrument was a failure. Although so sensitive that but 3-100,000,000,000 watt (see Appendix) is sufficient to make it produce an audible sound as a receiver, it lacked the qualifications necessary for a good transmitter. After numerous experiments, transmitters employing carbon in one form or another were found most

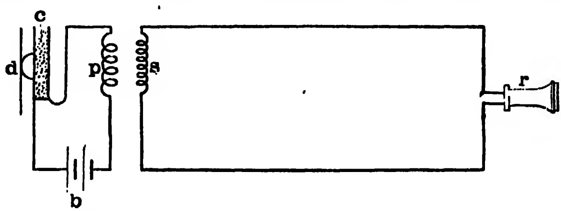


FIG. 8.—Simple Telephone Circuit for Transmitting in One Direction

satisfactory, and to-day none but carbon transmitters are used for distances over a few hundred feet.

The Principle of the Carbon Transmitter is based upon the fact that finely ground or pulverized carbon or graphite varies in electrical resistance according to the mechanical pressure brought to bear upon it. Under high pressure the resistance of carbon is low, but under a low pressure its resistance is comparatively high. If, therefore, at the transmitting end of a line, carbon of one form or another, as shown at *c* in Fig. 8, be placed in series with a battery *b* and an induction coil *ps*, sound waves of a voice striking against the

diaphragm *d* will cause varying pressures in the carbon and consequently a pulsating current in the circuit in which the battery and primary winding *p* of the induction coil are connected. The variations of the pulsating current will be in harmony with those of the voice, and will induce in the secondary winding *s* of the induction coil an alternating current which will have a frequency corresponding to that of the sound waves at the diaphragm of the transmitter. This alternating current will cause the distant receiver *r* to act as previously described and to reproduce the sounds of the voice at the transmitter. The form in which the carbon is used and the method of mounting it have given rise to many different kinds of carbon transmitters. Only a few of the more common forms will here be considered.

The Edison Transmitter employs the carbon in the form of a block as shown at *s*, Fig. 9. A metal casing *c* incloses the carbon, but is insulated from it except on the side *r*. The casing *c* is held within the metal chamber *h* by the bolt *d*. The circuit through the instrument from the binding post *a*, which is insulated from the chamber *h* by a hard-rubber bushing, runs by the conductor *o* to the right-hand side of the carbon block *s*, thence through the carbon to the uninsulated side and out through the bolt *d*, chamber *h*, and binding post *v*, which is in electrical contact with *h*.

Sound waves entering the mouthpiece *l* strike the diaphragm and cause it to vibrate. The vi-

brations thus produced are transmitted to the carbon block *s* through an ivory button *u* and the side of the casing *c*, and cause a varying pressure on the carbon. This varying pressure, as previously explained, causes a varying resistance and therefore a varying current in the transmitter cir-

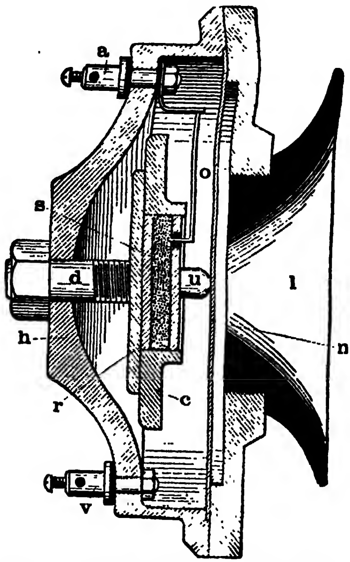


Fig. 9.—The Edison Transmitter

cuit, the variations of the current corresponding to those of the sound waves. The Edison transmitter is not a very sensitive instrument, lacking in flexibility between the ivory button and the carbon plate.

The Blake Transmitter, which now is not generally in use, but is mentioned here to illustrate

the principle, serves well on lines of moderate length, if kept in good adjustment. Fig. 10 shows the side and back of the transmitter at *A* and *B*, respectively. The carbon is in the form of a button *r* and is mounted in a case *m* supported by a steel spring *s*. A platinum ball *c* is supported between the carbon button *r* and the diaphragm *n*, the

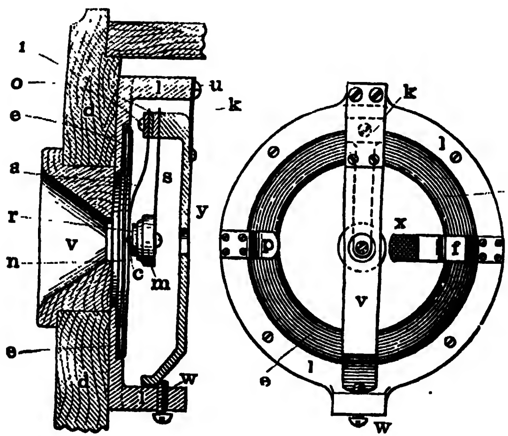


Fig. 10.—The Blake Transmitter

diaphragm being held against the receptacle *ll* and insulated therefrom by a hard-rubber circular sleeve *ee*. The platinum ball or contact piece is held rigidly by a German-silver spring *a*. The springs *s* and *a* are insulated from each other at *i* and both are supported by *y*, a heavy metal strip, which in turn is fastened to *ll* by the spring *k*. The pressure between the platinum contact, the carbon button, and the iron diaphragm is adjusted

by varying the position of the strip *y* by means of the screw *w*. The two metal strips *p* and *j* are used, the former to hold the sleeve *ee* in position, and the latter as a damper to check the vibrations of the diaphragm as soon as they have served their purpose so that they will not interfere with those following. For this reason, the end of the spring *j*, which presses upon the diaphragm near its center, is covered with a small cloth pad *x*. The entire apparatus is mounted in a wooden box *dd*, into which is fitted a wooden mouthpiece *v*.

Current entering the transmitter at the binding screw *o* passes down the spring *a* and through the platinum ball and carbon button to the spring *s*, thence through the spring *k* to the binding screw *u* and out. The vibrations of the diaphragm vary the pressure between the carbon button and the platinum contact, causing the necessary change of resistance in the transmitter circuit. The Blake transmitter, although low in first cost and requiring but little current to operate it, needs frequent and careful adjustments, and is so very sensitive to vibrations that special care is necessary to select for it a particularly firm support.

The Solid-Back Transmitter employs granulated carbon for the active material and is the one in most common use to-day. Fig. 11 shows a side view and a back view of this transmitter at *A* and *B*, respectively. The outer case *s* is of metal, shaped much in the form of an electric bell gong. To this is attached a metal cover *rr*

containing the mouthpiece. The granulated carbon can be seen at *c* inclosed in a brass chamber *mn*, made in two parts, which are screwed together. This chamber is supported by the collar and screw at *e* to the brass strip *k*, which, in turn, is screwed to the cover *rr*. On the inner sides of the chamber are two carbon blocks *a* and *v*, the latter together with a mica washer *ii* forming one side of the chamber, and the former a portion of the other

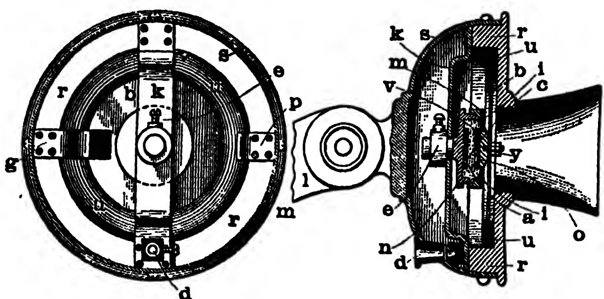


FIG. 11.—The Solid-Back Transmitter

side. These blocks are electroplated and soldered to their respective holders. The remaining parts of the inner walls of the chamber *mn* are lined with varnished paper. The support of the carbon block *v* consists of a disk-shaped piece of brass *o*, which, by means of the bolt *y*, is held firmly against the diaphragm *b*. The diaphragm is usually made of aluminum, thoroughly varnished, about 2½ inches in diameter and 0.022 inch thick. It is fastened to the cover *r* by the hard-rubber circular sleeve *uu* which overlaps it ¼ inch, and is

damped by the cloth-covered end of the spring *g*. The sleeve *u* is held in place by the clip *p*.

Connection with this transmitter is made by inserting the solid tip of an insulated connecting cord in the copper-faced hole *d*, which is insulated from the outer case by a hard-rubber bushing. A fine wire leads from here to *o*, and the circuit continues through the carbon plates and carbon granules to *e*, thence by the strip *k* to the outer metal case, and leaves the instrument by means of a connection to the metal arm *l* of the transmitter. The vibrations of the diaphragm are readily transmitted to the carbon block *v*, the mica washer being sufficiently elastic to permit of this, and the pressure on the carbon granules *c* varies accordingly, providing the necessary variations of resistance in the transmitter circuit. This variation is from about 35 ohms to 75 ohms.

The solid-back transmitter leaves little to be desired; it is sensitive to sound waves, but not to mechanical vibrations; the carbon blocks secure excellent contact with the carbon granules, and the latter give but little trouble by caking or "packing" because they do not become much heated by the current, owing to there being space above and below the blocks in which they can expand; the transmitter case is very small; and the chamber containing the carbon granules is both air-tight and moisture-proof. When properly set up, the transmitter requires no adjustment. In case it is necessary to examine the working parts, the in-

sulated connecting cord must first be withdrawn from the copper-faced hole *d;* then the screws which hold the cover to the case must be taken out, after which the working parts can be withdrawn.

The Induction Coil.—An induction coil is used in Fig. 8 for several reasons. This instrument, by providing a short local circuit for the transmitter entirely independent of the line circuit makes the variations in the resistance of the carbon large in comparison with the total resistance of the circuit in which it is connected, and therefore makes the action of the transmitter more effective. It also decreases the resistance of the line circuit by an amount equal to that of the local circuit, and by changing the pulsating current into an alternating one makes it more effective in exciting the diaphragm of the receiver. Another reason is its ability to alter the current and pressure relations of the primary and secondary circuits. This variation is proportional to the ratio of the number of turns in the primary winding p to the number of turns in the secondary winding s. Thus, with 300 turns in the primary and 2,400 turns in the secondary, the ratio is 1 to 8. A pressure of E volts (see Appendix) across the primary winding would, in this case, be raised to 8 E volts at the terminals of the secondary winding, while the primary circuit of 1 ampere would be reduced to $\frac{1}{8}$ ampere in the secondary or line circuit. The electric energy in both circuits, however, remains the same, namely, $E\ I$. As the resistance losses on the line are pro-

portional to the square of the current transmitted, it is obviously an advantage to make the transformation just noted.

The Construction of Induction Coils, *although* varying in details, follows the same general design. There is an iron core composed of soft iron wires, preferably No. 26 or 28, annealed to eliminate hard spots, and bound together in a round bundle. Enough wires are used to make a bundle ½ to ¾ inch in diameter, and their length is from 4 to 6 inches. These are packed into a fiber tube upon which is wound the primary coil. This coil generally has not less than 300 turns and is wound in two layers. The size of the primary wire depends upon the kind of batteries employed and varies considerably. No. 22 or 24 B. & S. gage would be considered an average size. The number of turns in the secondary winding is usually from 8 to 10 times the number in the primary winding, and the size of the secondary wire is such that the necessary number of turns are obtained in 5 layers or less. No. 32 to 36 B. & S. gage is generally considered advisable. Single silk-covered copper wire is mostly used for both the primary and secondary coils, and several thicknesses of paraffined paper are provided for insulation between these coils.

Fig. 12 shows a Monarch induction coil for ordinary local battery work. It is wound to a resistance of 1.7 ohms in the primary and 175 ohms in the secondary. The terminals are brought

out in heavy wire and are connected to binding screws on the fiber blocks *P* and *S*, the former of which contains the primary terminals and the latter the secondary terminals. The coil itself is covered with bookbinders' cloth as a protection from moisture.

The Battery.—Telephone work for the purposes considered in this book requires the use of primary batteries; in other words, batteries in which zinc is consumed by chemical action to generate

Fig. 12.—An Induction Coil

electricity. A battery consists of two or more cells connected, each of which comprises, besides the zinc or positive plate, another plate electronegative to the zinc, which may be either carbon or copper and which is called the negative plate. These two plates are placed in a glass vessel or jar containing an acid solution. The acid, attacking one of the plates more than the other, produces a difference of potential usually from 1 to 2 volts between them. Battery cells may be conveniently divided into two kinds: open-circuit cells and closed-circuit cells. The former are employed

where there is only an occasional use for the transmitters, and the latter where the transmitters are in almost constant use. All primary cells when working on circuits of such low resistance as those in which transmitters are used suffer a decrease in their electromotive force or voltage, and an increase in their internal resistance. This is due to the formation of small bubbles of hydrogen gas on the negative plate of the cell, which diminish the effective surface of the plate and set up an opposing electromotive force. It is, therefore, necessary to surround the negative plate with a depolarizer, the duty of the latter being to generate oxygen gas for combining with the hydrogen gas and thus setting it free in the solution. In open-circuit cells the depolarizer acts slowly and chiefly when the cell is not in use; in closed-circuit cells the depolarizer acts continuously.

The chief forms of open circuit cells are the Leclanché cell and the so-called dry cell. The chief forms of closed-circuit cells used in telephone work are the Fuller cell, the gravity cell, and the Edison cell. For furnishing current in the transmitter circuit it has become standard practice to use two Fuller cells in series, or their equivalent in the other forms of batteries mentioned. The cells are connected in series by joining with a copper wire the positive plate of one cell to the negative plate of the other, the remaining plates of the two cells serving at the terminals of the battery. When thus connected the total voltage is the sum of the

voltages of the two cells, and the total resistance of the battery is the sum of the internal resistances of the two cells. The best results are usually obtained by having both cells of the same form and size, and both must be of the same

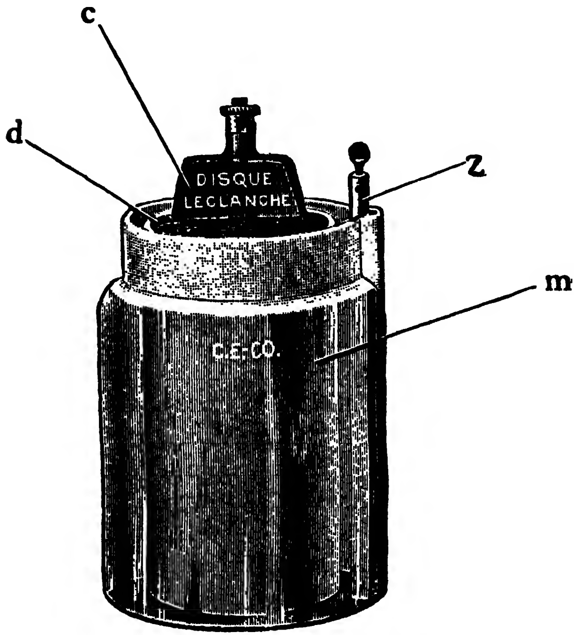


FIG. 13.—The Leclanché Cell

kind; that is, either open-circuit cells or closed-circuit cells. 26126

The Leclanche Cell, Fig. 13, comprises a negative plate of carbon *c* surrounded by the depolarizer, which consists of a mixture of crushed manganese-dioxide and crushed carbon in a porous cup *d*,

The positive plate is the zinc rod *z*, and this, together with the porous cup, is placed in a solution of sal-ammoniac and water in the glass jar *m*. The sal-ammoniac solution is best made by dissolving three parts of sal-ammoniac in ten parts of clean soft water. This solution passes through the porous cup and moistens its contents. The binding posts or screws on *c* and *z* form the terminals of the cell. The resistance of this cell is usually less than 1 ohm, and the electromotive force is about 1.5 volts.

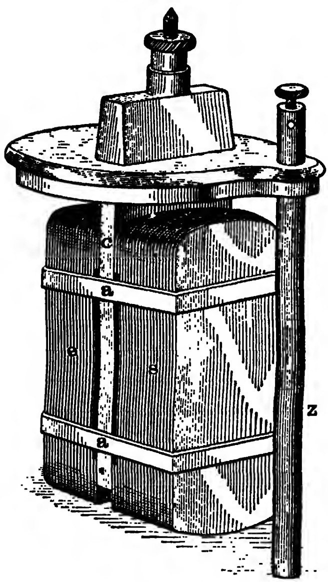


FIG. 14.—A Modified Form of the Leclanché Cell

A modified form of the Leclanché cell is shown in Fig. 14. The depolarizer here consists of two blocks, *e* and *s*, of manganese dioxide and carbon clamped around the negative carbon plate *c* by means of rubber straps *a a*. The elimination of the porous cup considerably decreases the internal resistance of the cell. The binding screws on the carbon plate *c* and zinc rod *z* are the terminals. Sal-ammoniac solution is used as in

the previous case, and the electromotive force is the same.

The Dry Cell, Fig. 15, is a convenient modification of the Leclanché cell and is widely used in telephone work. The outer case *z* is of zinc and forms the positive plate, connection with which is

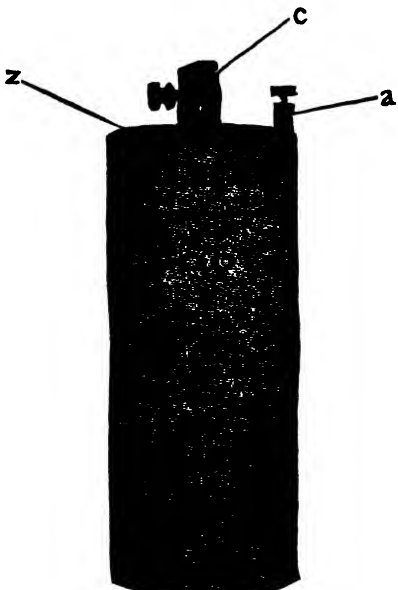


FIG. 15.—The Dry Cell

made at the binding screw *a*. Within this is packed the negative carbon plate *c* in a mixture usually composed of sal-ammoniac, chloride of zinc, dioxide of manganese, plaster, flour, and water. The top of the cell is sealed with bitumen. Although the mixture is not dry, it is non-spillable,

and in this respect is preferable to cells employing corrosive chemicals. The maintenance cost is practically nothing, and the first cost is low in comparison with other cells. On the other hand, the dry cell has a greater internal resistance than the wet cell, and its useful life is much shorter.

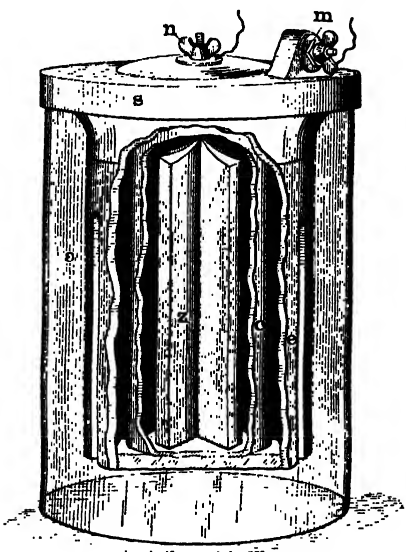


FIG. 16.—The Fuller Cell

The internal resistance is about 0.3 ohm, and the electromotive force 1.4 volts.

The Fuller Cell, Fig. 16, is especially well adapted for telephone work. It consists of a glass jar *a* containing a porous cup *c* in which is the zinc *z*. The porous cup is suspended from the top of the jar and is filled with diluted sulphuric

acid or a salt solution. The salt solution is made by mixing about 3 ounces of salt in a pint of water. The negative plate is carbon in the form of a cylinder *e* that surrounds the porous cup, and this also is suspended from a wooden or rubber cap *s* which closes the jar. The jar is filled with a solution of 3 parts bichromate of potash, 1 part sulphuric acid, and 9 parts water. About 2 ounces of mercury is placed in the porous cup with the zinc, for amalgamation; that is, the mercury combines with the zinc and eats the impurities from its surface, causing the zinc to present a clean surface to the acid. The binding screw *m*, attached to *e*, and the binding screw *n* fastened to *z*, form the terminals of the cell. The internal resistance is about 0.5 ohm, and the electromotive force is 2 volts.

The Gravity Cell, Fig. 17, has for its positive plate three sheets of copper fastened together as shown at *c;* these are spread out, and set on edge in the bottom of the glass jar *m*. A gutta-percha insulated copper wire *a* soldered to the copper extends up through the cell, forming one of its terminals. The negative zinc plate is cast with projecting fingers as shown at *z*, and on account of its general resemblance to a crow's foot this cell is sometimes called a "crow's-foot" battery. The zinc is suspended across the top of the jar and is provided with a binding screw as indicated. The solution used is copper sulphate, sometimes called blue vitriol, and water. It is formed by placing in the

bottom of the jar from 6 to 8 ounces of copper-sulphate crystals *n*, and then introducing water until the zinc is well covered. A saturated solution of copper sulphate forms around the copper and, after use, a zinc-sulphate solution forms around the zinc and floats upon the copper-sulphate solution. The two solutions, having different specific gravities, are thus kept apart, and as the copper-

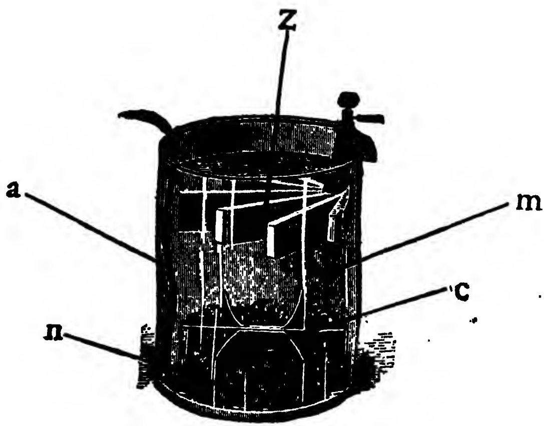


FIG. 17.—The Gravity Cell

sulphate solution has a deep blue color while the zinc sulphate is light colored, it is easy to distinguish them. The dividing line between them is called the blue line, and the name "gravity cell" results from the part gravity plays in the performance of the liquids. The internal resistance can be reduced, and the cell made immediately available for use after setting up, by using, instead of water, about half a pint of zinc-sulphate solution

from a battery already in commission or by pouring into the water 4 or 5 ounces of pulverized sulphate of zinc. The internal resistance of the cell is from 2 to 3 ohms, and its electromotive force is practically constant at 1.08 volts. Owing to the high internal resistance it is seldom used in

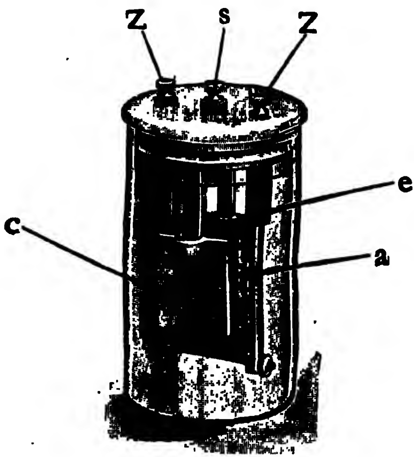


Fig. 18.—The Edison or Gladstone Cell

telephony except for the transmitter at the switchboard.

The Edison Cell, Fig. 18, employs two zinc positive plates *c* and *e*, and a slab *a* of pressed copper oxide for the negative plate. The plates are suspended side by side from the cover of the jar, the copper-oxide plate being held between the two zinc plates as shown. The jar is filled with a solution of caustic potash and water, on which is

poured a layer of oil to prevent the salts, which form, creeping up to the edge of the jar. In setting up the cell, only half of the sticks of caustic potash furnished by the makers should at first be placed in the jar. After water has been poured on them to within an inch of the top of the jar, and they have been dissolved by stirring, the remainder of the sticks may be added and the solution stirred as before. In wiring up the cell, the binding post *s* connected to the copper-oxide plate forms one terminal, and the binding posts *z* and *z* fastened to the zinc plates are coupled together and form the other terminal of the cell. The internal resistance is but 0.025 ohm, and the working electromotive force about 0.75 volt.

Conversing in Both Directions.—Fig. 19 shows a simple telephone circuit over which conversation can be carried on in both directions. It is simply a further development of the principles illustrated in Fig. 8, the apparatus and connections at both ends of the line being identical. As to the receivers it may be questioned why the permanent magnets in them (see Fig. 3) are necessary, now that there is an electromagnetic action to produce the attraction of the diaphragms. The reason is that the permanent magnets are essential for the reproduction of the proper pitch.

A Grounded Telephone Circuit is shown in Fig. 19; that is, the earth or ground is used as one conductor between the two stations *a* and *b*, in place of one of the line wires. Either a grounded circuit

or a two-wire (complete metallic) circuit is practicable in connecting the stations *a* and *b*. In the former case, connection with the ground at each station may be made either by fastening the ground wire to a water pipe or to a metal rod driven down to moist earth. The surface of the pipe or rod should be filed or scraped bright, the wire then wound around it, and a clamp placed over the wire and firmly bolted to the pipe. Another method consists of burying in moist earth below the frost

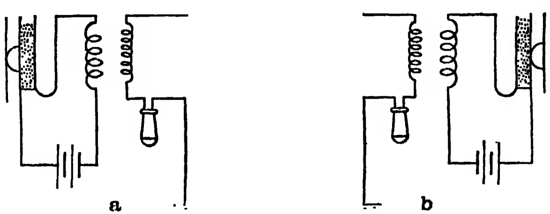


FIG. 10.—A Grounded Telephone Circuit for Transmitting in Both Directions

line, that is, 5 or 6 feet beneath the surface, a copper plate about 1 foot square to which the ground wire has been riveted, and soldered throughout its length over the plate. The plate should be surrounded on each side with a thin layer of crushed coke or charcoal about pea size to protect it against corrosion from too direct contact with the earth.

Grounded telephone circuits are not usually as satisfactory as complete metallic circuits, especially in the vicinity of electric-light and railway

lines, on account of the inductive disturbances caused by stray earth currents. With good earth connections the grounded portion of the line has a negligible resistance, but at best grounded telephone circuits are serviceable only for lines of moderate length and as the saving in line wire in such cases is small they even then hardly compensate for the risks of disturbances incurred.

The Signal Receiving and Sending Apparatus. In addition to the talking apparatus already considered there must be at each point where a telephone equipment is located, some means of signaling, so that a person *A* may know when a distant party *B* wishes to converse with him over the wire, and also to enable *A* to call *B* to the telephone. For the purposes here considered, the signal receiver is a magneto bell, and the signal sender is a magneto generator. 20, 126

The Magneto Bell and Generator are shown diagrammatically in Fig. 20. The bell *A* comprises an electromagnet *cc*; also a soft-iron armature *v* pivoted at its center so as to permit of its oscillating, and, by means of the clapper *o* attached to it, striking alternately the gongs *h* and *l*. The bell is actuated by an alternating current, and depends for its operation on the permanent magnet *ns* which induces in the armature *v* a south pole at *S* and two north poles at the ends *N* and *N*. The permanent magnet *ns* also induces in the yoke *u* of the electromagnet a north pole at *N′* and two south poles at the ends *s′* and *s′*. As the induced

polarities are approximately equal in strength, and in each case a north pole is opposite a south pole, their combined effect upon the armature *v* is neutral, and it remains balanced. As soon as an alternating current passes through the magnet coils, which are wound in opposite directions around the cores, this current when flowing in one direction will strengthen one pole of the electromagnet and weaken or reverse its other pole, un-

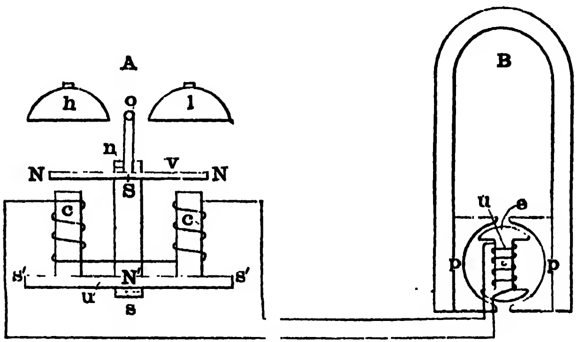


Fig. 20.—Diagram of Magneto Bell and Generator

balancing the armature and causing it to swing about its pivot so that the clapper *o* strikes one of the gongs. At the next instant the alternating current reverses its direction of flow, strengthening the pole which formerly was weakened, and weakening or reversing the other pole of the electromagnet. This will cause the armature to be drawn in the opposite direction and the clapper to strike the other gong. So long as the alternating current continues to flow, this action will be repeated

and the bell will continue to ring. Direct current, however, would have no effect upon the bell unless an interrupter were used. The action of the permanent magnet in the operation of the armature has led to the instrument being sometimes called a "polarized" bell or ringer.

The magneto generator *B*, Fig. 20, is a simple form of alternating-current generator. A coil of insulated wire *u*, wound upon an iron core *e*, is revolved by hand in the magnetic field produced by the permanent horseshoe magnet *p p*. The cutting of the lines of magnetic force by the coil of wire induces in the coil an alternating current which acts upon the magneto bell *A* as just described. Ordinarily, three or four horseshoe magnets are employed so there will be a strong field; these are arranged side by side with like poles adjacent. Conductors sliding on a pair of metallic rings collect the current generated in the armature. Owing to a high reduction gear being used between the armature shaft and the hand wheel, but a few rapid turns of the latter are necessary to drive the armature at a sufficiently high speed to generate the required power to ring the bell.

In comparison with the ordinary direct-current electric bell and battery, the generator of the magneto set gives a much higher voltage than is usual in the battery, with no trouble from acids and with less cost of operation; the generator and bell being always on closed circuit, there are also fewer contacts to burn, oxidize, or in other ways cause

trouble. These are some of the reasons why the magneto set has become widely used as a signal-sending and -receiving device.

Typical Forms of Magneto Bells are shown respectively in Figs. 21 and 23. The first one presented is a Stromberg-Carlson polarized ringer wound to a resistance of 1,600 ohms. Adjustment of the armature with respect to the poles is secured,

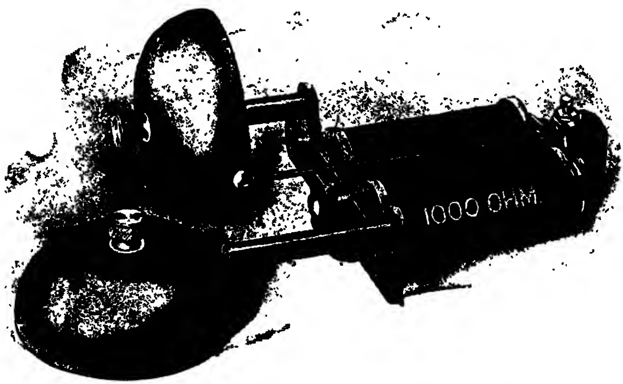


FIG. 21.—Polarized Magneto Bell or Ringer, with One Gong Removed

as shown in Fig. 22, by having the armature *CC* supported upon the spring plate *DD*, which is provided with two holes to receive the ends of the magnet cores *EE*. A cross-bar *FF* is mounted over the poles, and into this is threaded the screw *B* which projects through a hole in the permanent magnet *A* and has a shoulder bearing on the plate *DD*. Turning the screw *B* to the right or left moves the plate *DD* toward or away from the mag-

net cores and thus enables the proper adjustment of the armature to be secured. The clapper *G* is bolted to the armature as shown. The coils are wound with silk-insulated wire and are covered with heavy linen cloth to protect them from injury.

Fig. 23 shows a Kellogg magneto bell designed somewhat differently from the one shown in Fig.

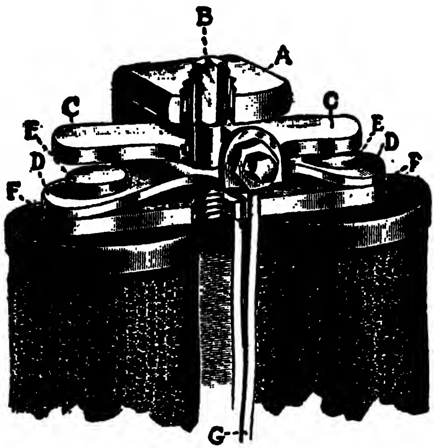


FIG. 22.—Armature End of Ringer Shown in Fig. 21

21. This form of ringer is called a "biased" bell, and is used where a selective signal is wanted, that is, where there is more than one bell connected to a circuit and it is desired to be able to ring one or the other of them at will. Its construction differs from the polarized bell only in the use of a spring *s*, which is fastened to either side of the armature *e* so as to pull that end of it toward the magnet. The result is that the bell will not respond to cur-

rents of one polarity, but will respond to currents of the opposite polarity. It is necessary in any biased bell to determine by trial the side on which the spring should be placed to make it operate on a positive or a negative current.

A Typical Form of Magneto Generator is shown in Fig. 24. This 3-magnet Acme generator will be readily understood from the general description previously given. At the left end, however,

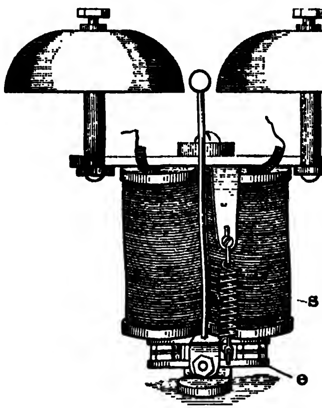


FIG. 23.—Biased Ringer

an automatic shunt *s* is fitted, the operation of which will be explained later on. The three horseshoe magnets *h*, etc., are held to the frame by the bolts *a* and *c*; each magnet is capable of lifting 5 pounds. The armature core on which the windings are placed is built up with sheet-iron punchings, each shaped like those shown at *a*, etc., Fig. 25. These punchings are threaded on the armature

shaft *c* and bolted together as there indicated, after which the core has the appearance shown in Fig. 26. Silk-insulated copper wire, either No. 34 or 36 B

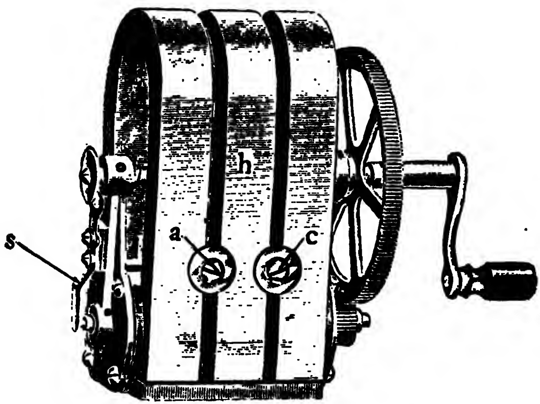


FIG. 24.—Magneto Generator

& S. gage, is then wound lengthwise over the core. The completed armature, Fig. 27, has a resistance of from 300 to 1,000 ohms and develops from 80

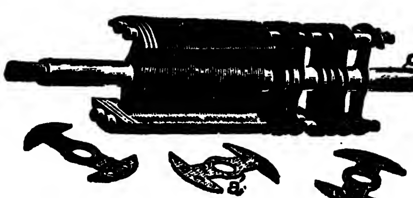


FIG. 25.—Method of Building Up the Generator Armature Core with Sheet-Iron Punchings

to 120 volts. The resistance of the armature winding must not be confused with the resistance rating of a magneto generator. This latter refers to the

number of ohms resistance through which the generator can ring its own bell. A 10,000-ohm generator, for instance, is one which will ring the bell through 10,000 ohms resistance. Magneto generators are also rated according to the number

FIG. 26.—The Completed Armature Core

of permanent horseshoe magnets they contain; as previously stated, 3- or 4-magnet generators are the usual sizes employed.

Connections of the Talking and Signaling Apparatus.—Telephone apparatus must always be connected so that the following conditions are satisfied: (1) When the talking circuit is not in use, the bell must be connected so as to receive

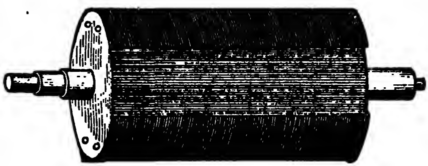


FIG. 27.—The Completed Armature

a signal. (2) When a signal is to be sent, the generator must be connected to the line wires. (3) When the talking circuit is in use, the receiver must be connected to the line wires, and the transmitter, battery, and the primary windings of the

induction coil must be connected in a local closed circuit. (4) *When the talking circuit is not in use, the battery circuit must be opened.* It is possible to satisfy these conditions with the signaling apparatus either in series with the line or bridged across it.

The Series Connection is shown in Fig. 28, *b* representing the magneto bell, *g* the magneto generator, and *m* and *n* the line wires. When the line is not in use for conversation, the receiver *r*

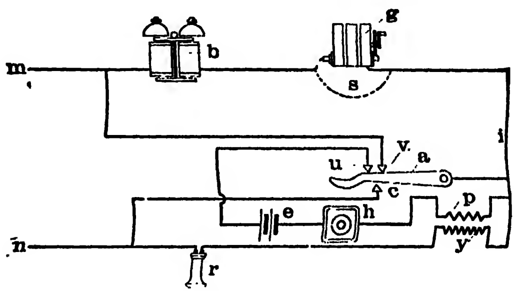


Fig. 28.—The Series Connection.

is hung on the end of the metal hook switch a, and its weight keeps a down so that it touches the contact piece c. The generator *g* is provided with a shunt *s*, which forms a low-resistance path around *g* when the generator is not in use. The shunt, however, is opened automatically when the crank handle of the generator is turned in the act of ringing the bell at the other end of the line.

Signaling current coming in at *m*, passes through the magnet windings of the bell *b*, the shunt *s*, the hook switch *a*, the contact *c*, and out at *n*,

ringing the bell *b*. Condition (1) is, therefore, satisfied. *With the exception of the shunt s being* opened as already explained, and the armature winding of the generator introduced, the circuit through the apparatus shown remains the same when the generator *g* is operated to signal a distant party, so that condition (2) is also satisfied. The party signaled by the ringing of the bell *b* removes the receiver *r* from the hook of the switch *a* and places it to his ear, whereupon *a* is drawn upward against the contact pieces *u* and *v*, as in Fig. 28, by means of a spring. This action leaves the receiver *r* connected to the line wires by the circuit *m v a l y r n*, and places the transmitter *h*, the battery *c*, and the primary winding *p* of the induction coil in the local closed circuit *c u a l p h*, satisfying condition (3). Condition (4) is satisfied when the receiver *r* is replaced on the hook switch *a*, because the contact at *u* in the battery circuit is then opened.

The Automatic Shunt *previously referred to in* connection with the magneto generator, is shown in one form in Fig. 29. A coil of the armature winding is represented at *c*, upon the armature core *e*. One wire of the signaling circuit is connected to the armature shaft, and the other wire to the pin *o* which is secured to an insulated bushing *a* inserted in one end of the armature shaft. The shunt is in the form of a spring *g*, screwed at one end to the iron core of the armature and carrying at the other end a weight *w*. Owing to

the tension of the spring *g*, its free end normally presses against the pin *v*, short-circuiting the armature winding. When the armature is put in motion, however, centrifugal force causes the weight *w* to fly out, separating the spring from *v* and forcing it in contact with the stop *p*. As *p* is in connection with the iron armature core, the armature winding is thereby introduced in circuit and the shunt is opened. As soon as the armature ceases

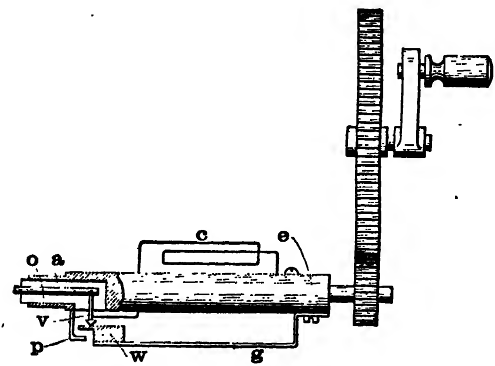


FIG. 29.—Automatic Shunt of the Magneto Generator

to revolve, the spring again comes in contact with *v* and closes the shunt circuit. This device is often called a "centrifugal" shunt owing to its action being caused by centrifugal force.

The Hook Switch for a series connection is shown in one form in Fig. 30. It is pivoted at *o* and supported at the other end by the spring *s*, being thus free to move up and down through the slot in the box in which it is mounted. Its

action in making connection with the upper contacts *w* and *v*, and the lower contact *c*, when the receiver is respectively off or on the hook *h*, is already familiar to the reader. The hook switch is usually of brass, nickel-plated, and the springs are of steel with platinum tips. Platinum tips are employed because they do not corrode, but present a good wearing and contact surface.

Details of Wiring a Series Station.—In order that the telephone instruments indicated in the plan of

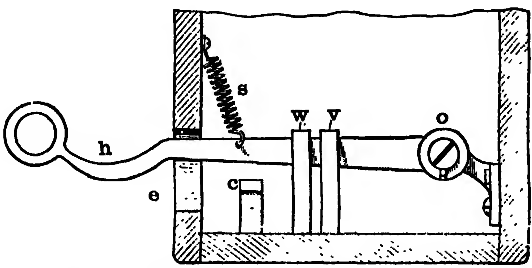


FIG. 30.—One Form of the Hook Switch

wiring, Fig. 28, be properly protected from injury and occupy as little unnecessary space as possible, it is customary to assemble them in a wooden case such as that shown in Fig. 31, and fasten the case to the wall. The apparatus thus grouped together is known as a telephone set or station; in the style of case shown it is designated as a solid-back wall set. The wooden box *a* contains the magneto generator, magneto bell, and switch arm. The switch arm projects outside the box and holds the receiver. The semi-cylindrical iron case *b*

contains the induction coil and provides a support for the transmitter arm. The wooden box *c* holds the battery, which consists of two cells, and its sloping top affords a place for recording notes received through the telephone. The set should be located in a convenient and accessible, yet out-of-the-way place on a solid wall free from vibration; it should be fastened to the wall with screws at each of the four corners and at such a height that the mouthpiece of the transmitter when in its normal position will be about 5 feet above the floor.

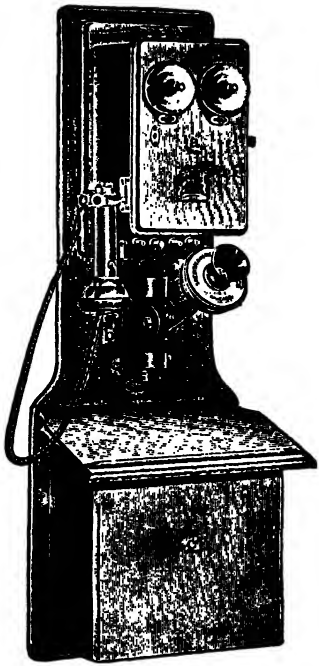


FIG. 31.—A Solid-back Wall Set

The Wiring Inside of the Telephone Set is done with No. 18 B. & S. gage cotton-covered stranded copper wire, according to the diagram given in Fig. 32. In some sets the connecting wires are run in grooves in the backboards or bases and covered with hot bees-wax to exclude moisture. The conductors leading to the line wires are con-

nected respectively to the binding posts 1 and 3, and to the binding post 2 is connected the ground wire from the lightning arrester *a*. The receiver *r* is connected between the binding posts 4 and 5,

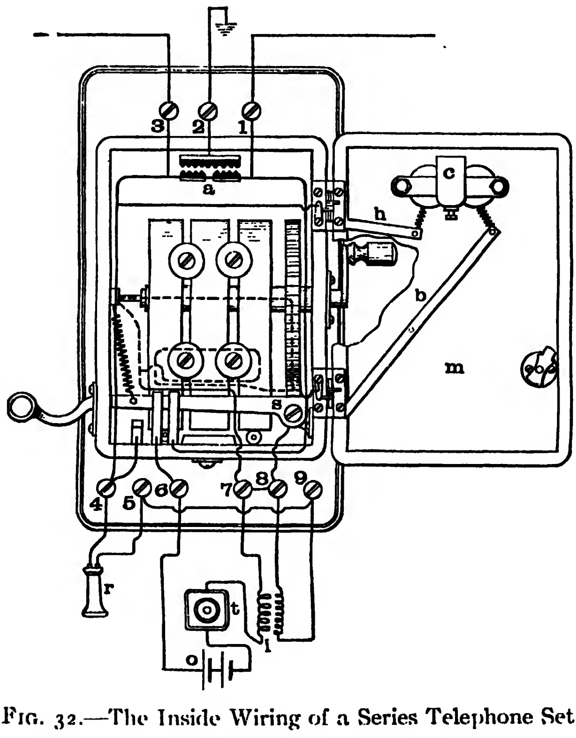


FIG. 32.—The Inside Wiring of a Series Telephone Set

usually by 2½ feet of No. 18 B. & S. gage stranded twin conductors, separately insulated with a rubber covering and together overlaid with strong worsted or silk braid. These conductors generally terminate in solid tips, and the braid is usually extended

to connect either with the case or the magnetic system of the receiver so that there is no strain on the conductors. Two cells of battery *o*, *the transmitter t, and the primary winding of the induction* coil *i* are wired to the binding posts 6 and 7 while the switch arm *s* and the secondary winding of the induction coil *i* are connected between the binding posts 8 and 9. The bell *c* is mounted on the door *m* of the magneto box, which is open in Fig. 32 to show the interior connections. It is wired to two metal strips *h* and *b*, which, in turn, are soldered to the hinges of the door. On the inner side of each hinge is fastened a little spring which presses upon the opposite face of the hinge and insures good electrical contact with the bell circuit when the door is closed. The dotted lines in Fig. 32 indicate the circuits through the magneto generator and its automatic shunt, as shown in Fig. 29. These circuits, as already explained, are formed by the parts of the apparatus itself, and, therefore, are not a part of the present wiring; they are, however, indicated in the diagram to make clearer the connections to them from the lower hinge and the binding post 7.

The Lightning Arrester is used to protect the telephone set from lightning discharges upon the line wires, by providing for such discharges a more direct path to earth than that afforded by the telephone instruments. The Stromberg-Carlson carbon-block arrester shown in Fig. 33 is similar to the one indicated at *a*, Fig. 32. It consists of

two sets of carbon blocks, *c d* and *e s*, held between the brass springs or clips *m n* and *u v*. The two carbon blocks in each set are separated by thin strips of mica perforated with holes, and the binding post *r*, with which the central clips and carbon blocks are in electrical contact, must be carefully connected to earth by as short and straight a conductor as possible. The binding posts *b* and *h* must be joined to the interior circuits of the telephone set and to the line wires as already explained. If, then, a lightning discharge comes in

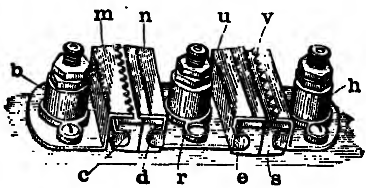


FIG. 33.—Lightning Arrester

on either of the line wires, its high voltage enables it to jump the short space between the carbon blocks and follow the ground wire to earth; this it does in preference to traversing the inductive circuit through the instruments. Telephone currents being of comparative low voltage cannot cross the space between the carbon blocks and, therefore, are not diverted from their course by the arrester.

The Magneto Bell in a series telephone set offers the only appreciable resistance through a station when the talking circuit is not in use. If the re-

sistance of the bell windings is small, a number of series telephone sets as in Fig. 34 can be joined in series upon a line, and the ringing current from any one of them will operate all of the bells simultaneously. The magnet coils of ringers in series telephone sets are, therefore, wound to as low a resistance as possible; 80 ohms is considered standard practice, that is, 40 ohms per coil with the 2 coils joined in series. Their cores are also made as short as possible to reduce any unnecessary impedance to the alternating current from the magneto generator. Although 4 stations are represented in Fig. 34, 2, 3, or more than 4 can be joined in series connection by following the method there shown; the grounded line wires at the 2 end stations will serve for

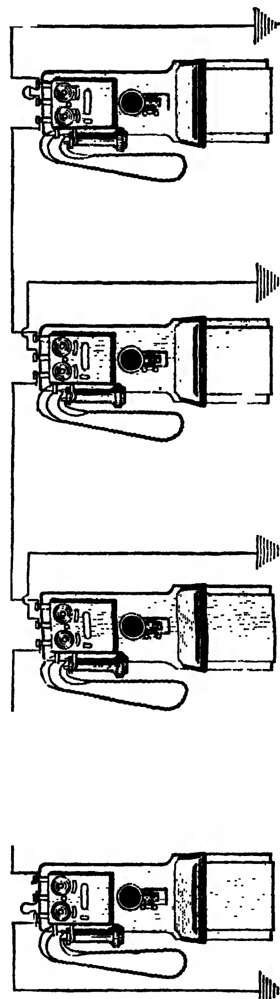


Fig. 34. Method of Wiring Series Telephone Sets on a Grounded Circuit

the lightning-arrester grounds if the center and end binding posts on the telephone sets at these stations be joined together as indicated. Fig. 35 shows 4 series telephone sets wired in series on a complete metallic circuit. The ground is then used only for the lightning-arrester connections.

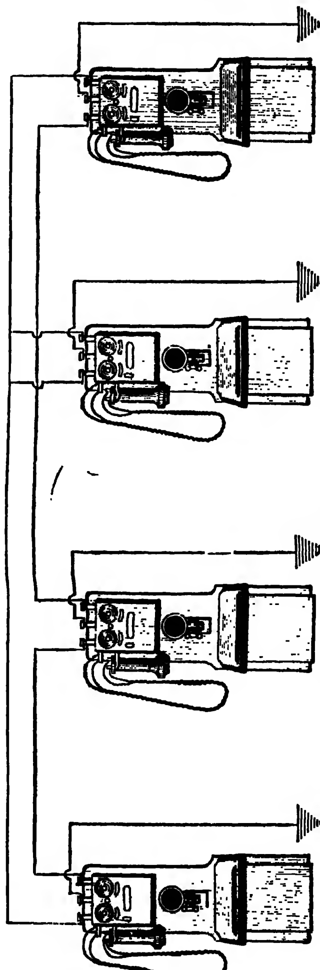


FIG. 35.—Method of Wiring Series Telephone Sets on a Complete Metallic Circuit

The Interior Wiring Between the Telephone Set and Line Wires is preferably done with No. 18 B. & S. gage rubber-covered stranded copper wires twisted in pairs, unless the conductors are to be much exposed, in which case it is advisable to use No. 16 B. & S. gage rubber-covered stranded wires. The rubber insulation on the No. 18 should be at least $\frac{3}{32}$ inch thick, and on the

No. 16 at least $\frac{5}{32}$ inch thick. Copper wires in sizes of 19 and 20 are also used for this kind of wiring, but they are not considered so desirable. A table of dimensions, resistances, and current-carrying capacities of copper wires including No. 16, 18, 19, and 20 B. & S. gage is given in the Appendix. It will be noticed from this table that the current-carrying capacity of the No. 18 is 5 amperes. As far as the current-carrying capacity is concerned, much smaller wire could be used, as telephone currents for the work considered in this book seldom exceed $\frac{1}{10}$ ampere, but owing to the mechanical weakness of smaller wire rendering it liable to be broken or stretched, no smaller sizes than No. 18 should ordinarily be employed In making connections, the insulation of the wire must be thoroughly scraped off and the wire made clean and bright at the points of contact. Whenever two wires are joined together, the connection should be soldered.

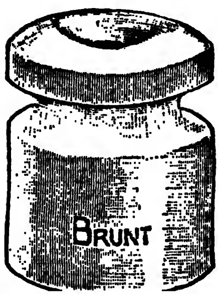


FIG. 36.—Porcelain Insulator for Interior Telephone Wiring

Wires must never be installed nearer than 1 inch to any kind of piping, and if it be necessary to cross pipes upon which moisture is liable to form, the wires should be led over rather than under them. Porcelain insulators, No. 5, such as are shown in Fig. 36, should preferably be used to support the wires, although the latter may be

fastened in place in any neat, secure, convenient, and workmanlike manner. Short single lengths of the insulated telephone wire can be used as tie wires in case porcelain insulators are employed. A porcelain insulating tube, Fig. 37, placed with the head *c* at the entrance hole, affords excellent protection for the wires through walls and other partitions; continuous flexible tubing or conduit is next best; but if neither tube nor tubing is avail-

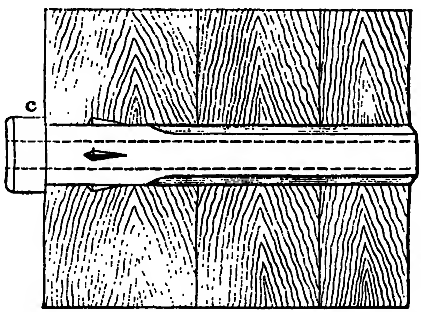


FIG. 37.—Porcelain Tube for Protecting Wires from Partitions and Walls

able, the wires should be wrapped with two layers of insulating tape.

Fishing for the wires between walls or under floors is done by boring 2 holes in the wall or floor along the desired path, pushing a flat spring wire from one hole toward the other, and catching it through the latter hole with a wire hook. By means of the spring wire, the flexible conduit containing the telephone wires may then be drawn into position. The flexible conduit or extra cov-

ering of the wire should extend in a continuous length between the entrance and exit holes, projecting beyond them about 1 inch in each case. Telephone wires must never be installed nearer than 6 inches to any electric light or power wire in a building, unless incased in porcelain tubing or flexible conduit so secured as to prevent its slipping out of place.

The wires leading out of the building should be No. 14 weather-proof wire, protected from the

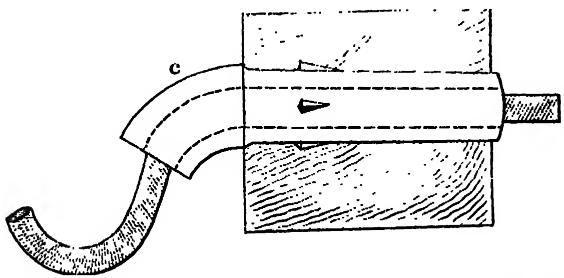


FIG. 38.—Porcelain Drip Tube for Protecting the Wires from the House Wall and Preventing Water from Following the Wires Inside

house walls either by a straight porcelain tube like that in Fig. 37, placed so as to slope slightly upward from the outside, or by a porcelain drip tube as shown in Fig. 38, placed with the head *c* outside the building. The slanting of the tube in the former case, or the drip loop in the latter case, effectually prevents water from outside following the wires within.

Figs. 39 and 40 show, respectively, one method of wiring between the house and the first pole in

the case of a single or grounded line and in the case of a double or complete metallic line. In both illustrations, *a* represents the porcelain tube, *c*

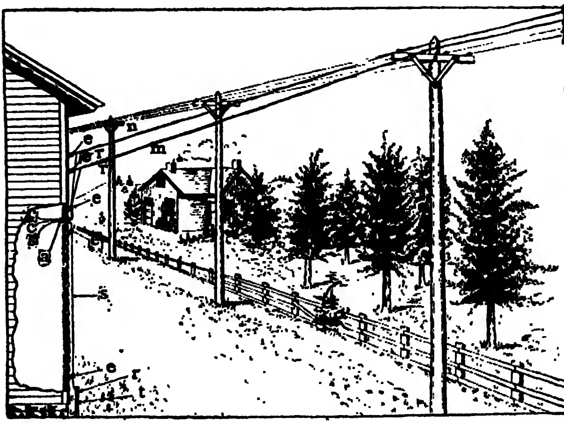


FIG. 39.—Method of Wiring a Grounded Telephone Line between the House and the First Pole

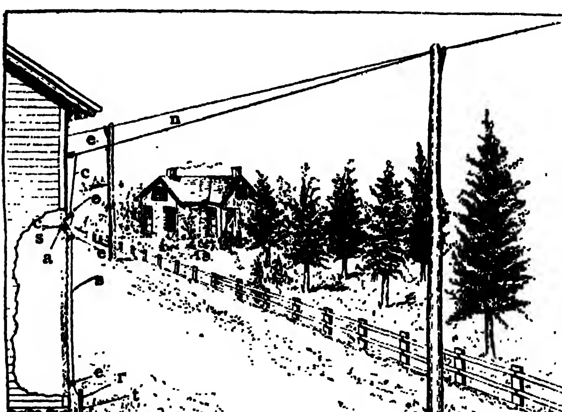


FIG. 40.—Method of Wiring a Complete Metallic Telephone Line between the House and the First Pole

the conductors leading to the line wires, *n* the line wires, *s* the ground wire, *t* the ground rod, *e* porcelain insulators, and *r* the soldered connections.

The Wiring of the Protective Apparatus does not always follow that shown at *a* in Fig. 32; in fact, in recent practice the lightning arrester is seldom mounted on the telephone set but is placed on a non-combustible, non-absorptive insulating base immediately inside the building at the point where the line wires enter. As lightning protection is necessary only from those discharges coming in from the line wires, this latter method is preferable to the former in that it conducts the discharges to ground by a more direct path.

Although in many telephone installations a lightning arrester which will operate with a difference of potential of 500 volts is the only protection provided at a station, the best practice consists in using in addition to the lightning arrester a fuse and a heat coil on each side of the line. The fuse is intended to open the telephone circuit in case the line wires become crossed with electric-light or power circuits, the stronger current of these circuits melting the fuse wire in passing through it. The heat coil is also intended to warm up and melt out with a current of sufficient strength to endanger the instruments if continued for a long time, but of so low a voltage that it would not traverse the lightning arrester, and of so small an amperage that it would not melt the fuse wire

just mentioned. These small currents are often called "sneak" currents.

The protective apparatus just mentioned must be connected so that the fuses protect the lightning arrester and heat coils. On a grounded circuit, but

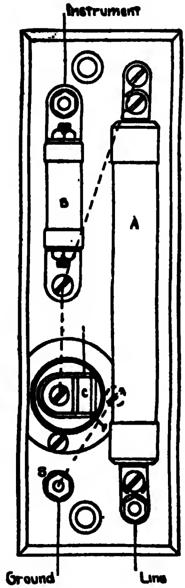


FIG. 41

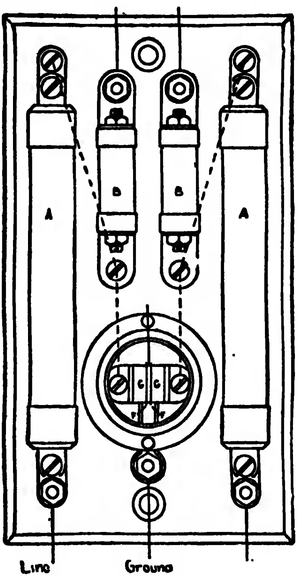


FIG. 42

FIG. 41.—Combination Set of Protective Apparatus for a Grounded Telephone Circuit, Showing the Necessary Wiring

FIG. 42.—Combination Set of Protective Apparatus for a Complete Metallic Telephone Circuit, Showing the Necessary Wiring

one set of these devices is used, connected between the line wire and the telephone set. Figs. 41 and 42 show D. and W. combination protective sets

for a grounded circuit and a complete metallic circuit, respectively. In the former, the circuit runs from the line through the 2-ampere fuse *A* to the 0.3-ampere heat coil *B* and the lightning arrester *C*, as indicated by the dotted lines. The other terminal of the heat coil is connected to the telephone set, and the other terminal of the lightning arrester is connected to ground. The ground wire from the telephone set is fastened to the binding post *s* which is also directly connected with the grounded side of the arrester. For a complete metallic circuit, the protective apparatus in Fig. 41 is simply duplicated, and the connections are made as in Fig. 42. In both cases the apparatus is mounted on a porcelain block.

The Fuse should be of the inclosed type, in order to more securely protect the fuse wire from mechanical injury, and also to enable the arc, which forms when the fuse blows, to be more readily extinguished. The arc is extinguished either by placing in the tube a compound that will suppress the arc or by allowing the vapor, which forms inside the tube when the fuse melts, to blow out the flame.

The Heat Coil comprises a small coil of German-silver wire of from 5 to 50 ohms resistance, depending upon the sensitiveness desired; this surrounds a pin and is fastened to it by an easily fusible solder. A spring bears upon the pin so that when released by the fusing of the solder it comes in contact with the ground connection and opens the circuit passing through the coil. The heat coils in Figs. 41

and 42 are rated to operate at 0.4 ampere in less than 15 seconds, and are inclosed in cases of non-conducting material.

The Location of the Protective Apparatus depends largely upon whether it is all combined on one base as in Figs. 41 and 42, or whether the fuse is separate from the lightning arrester and heat coil. In the former case, it is usual to mount the apparatus immediately inside the building at the point where the wires enter, so that the inside wiring will be exposed as little as possible to abnormal currents; in the latter case it is considered best to mount the fuse on the house wall outside the building, and the lightning arrester and heat coil close to the telephone set, so that the entire inside wiring is guarded, and the delicate parts of the protective apparatus can be easily reached in case of trouble.

The Operation of Series Stations.—When a party at one of the telephone sets on a series line desires to communicate with a party at another set, he turns the crank handle of his magneto generator at intervals so as to give a certain number of rings throughout all the bells, ringing once to signal one station, twice to signal another, and so on according to a predetermined code. The party he wishes, recognizing the number of rings as corresponding to his instrument, goes to the telephone and removes his receiver from the hook, whereupon he is in telephonic communication with the party who desires to speak to him. Ob-

viously, but two parties can use the line at one time, and any of the others can, if they so desire, hear all that is being said over the line by simply listening at their receivers. Another disadvantage, which increases with the number of stations connected, is the annoyance caused by all the bells ringing whenever a signal is sent.

An Extension Bell in a Series Station is often of great convenience, enabling two parties in different rooms, for example, to utilize the same telephone set and each have their own signaling code.

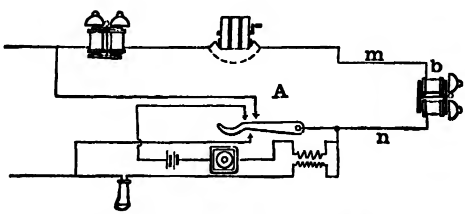


FIG. 43.—Diagram of Wiring for an Extension Bell in a Series Station

Fig. 43 shows the wiring for an extension bell *b* in a series-connected station *A*. No. 18 B. & S. gage rubber-covered wire should be used for the leads *m* and *n*. In the telephone set, Fig. 32, the extension bell would be connected between the binding post 7 and the wire leading to this binding post from the magneto generator. The coils of the extension bell should be wound to a resistance of 80 ohms.

The Bridging Connection.—The bridging connection of the signaling apparatus with respect

to the line is shown in Fig. 44. Comparing this diagram with the series connections, Fig. 28, the following points of difference are to be noted. The magneto generator *a* is connected directly across the line wires *m* and *n*. One end of the armature winding terminates in an insulated pin

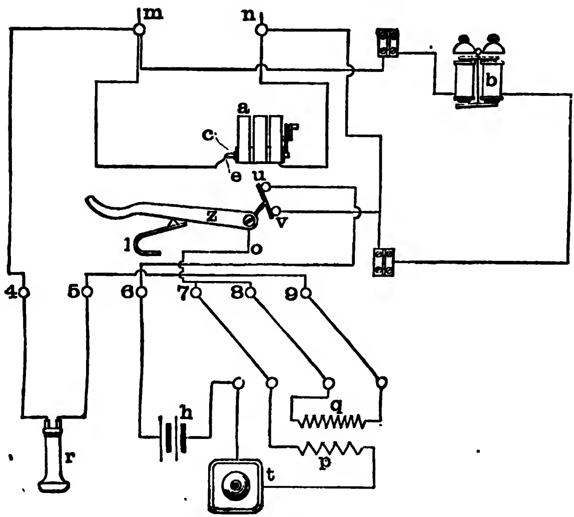


FIG. 44.—The Bridging Connection

c in the armature shaft, and the other end on the armature core. When the generator is not in use, the armature circuit is automatically opened at *e* by the pin *c* being separated from the end spring. When the crank handle of the generator is turned, a spring mounted in the hub of the gear wheel forces the armature shaft forward so that *c* makes contact with the end spring and closes the circuit. The mag-

neto bell *b* is permanently bridged across the line wires and, being thus continuously in circuit, must offer a high impedance to the talking current so as not to divert it from its proper course. The ringer coils are therefore wound to a high resistance, generally 1,000 or 1,600 ohms, that is, 500 or 800 ohms per coil, on comparatively long iron cores. As far as the connections for the signaling apparatus are concerned, it is thus seen conditions (1) and (2), previously given, on page 37, are satisfied.

FIG. 45.—Hook Switch with Horizontal Spring Contacts

The hook switch *z* is connected permanently with both windings of the induction coil by the wire *o*. When the talking circuit is in use, the receiver is off the hook switch, permitting the latter to be forced up by the spring *l* and make contact at *u v*; this action connects the receiver to the line wires by the circuit *m* 4 *r* 5 9 *q* 8 *o v n*, and the transmitter, battery, and the primary winding of the induction coil are connected in the local closed circuit *h* 6 *u o* 7 *p t*, thereby satisfying condition (3). When the talking circuit is not in use, the

receiver is on the hook switch; the weight of the receiver then overcomes the force of the spring *l* and, by pulling the switch *z* down, opens the contact made at *u v* and thus opens the battery circuit, satisfying condition (4).

Different forms of the hook switch for a bridging connection are shown in Figs. 45 and 46. In the Kellogg hook switch, Fig. 45, the contacts are formed by a series of German-silver springs at *a*, insulated from each other, and from the frame and the hook lever *r*, by hard rubber. The contact points are of platinum, riveted to the springs. The main spring *b* is also of German silver, and is fastened so as to act on the lever *r* through a short moving distance. In the Swedish-American desk-set hook switch *A*, Fig. 46, the contact springs are mounted vertically at *c*, and the main spring has the form shown at *d*. The principles of operation involved, however, are the same as previously described. Connection with the contact springs is made by the flexible wire cord shown entering the base *s* through the hard-rubber bushing *e*; and when the parts are assembled as shown at *B*, Fig. 46, the skill of the designer is appreciated.

Details of Wiring a Bridging Station.—The wooden box shown in Fig. 31 for housing the telephone apparatus of a series station would serve equally well for holding the apparatus of a bridging station, so that as far as outer appearances are concerned the two kinds of telephones may be similar. The wiring inside of the bridging tele-

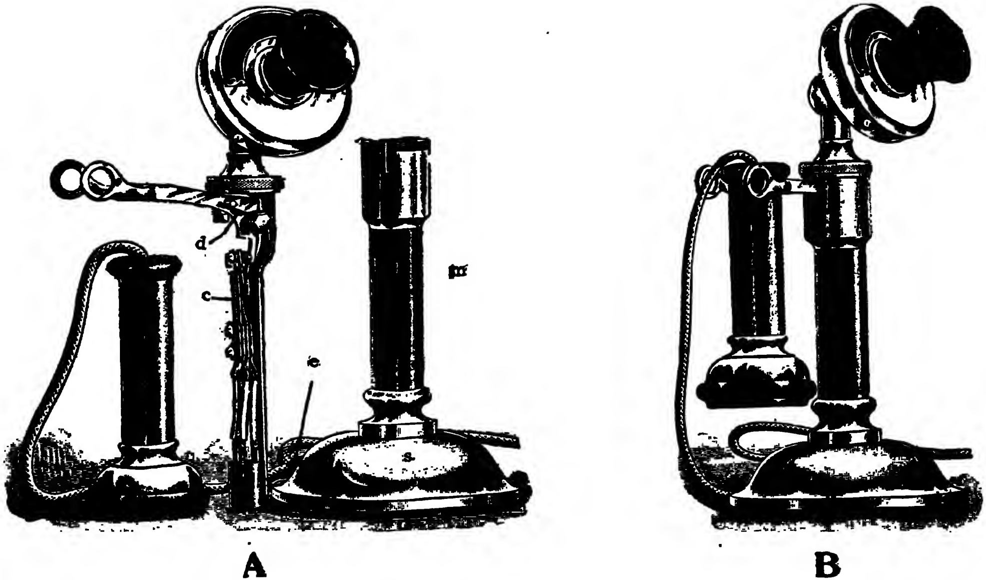


FIG. 46.—Hook Switch with Vertical Spring Contacts as Used in a Desk Telephone Set

phone set, however, differs considerably from the former case, as already noted, and is shown in detail in Fig. 47. Particulars relating to the kind and size of wire to use, the connections for the

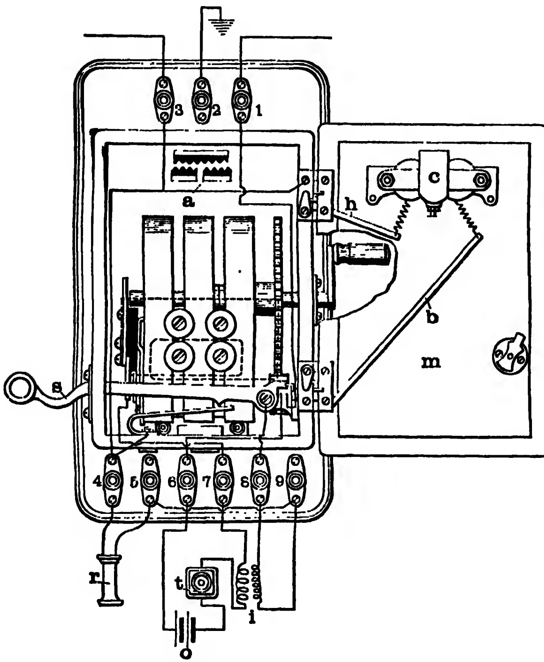


FIG. 47.—The Inside Wiring of a Bridging Telephone Set

protective apparatus, and the wiring up to the line wires are identical with those already given for the series station, and the reader is referred to them for further details.

An Extension Bell in a Bridging Station is just

as convenient and as readily connected as in a series station. The two wires from the binding posts *m* and *n* of a bridging extension bell, Fig. 48, would be connected respectively to the binding posts 1 and 3, Fig. 47. The ringer coils in the Acme extension bell shown are wound to a resistance of 1,000 or 1,600 ohms to correspond with those in the main telephone set.

The Wiring for a Desk Set is shown in Fig. 49.

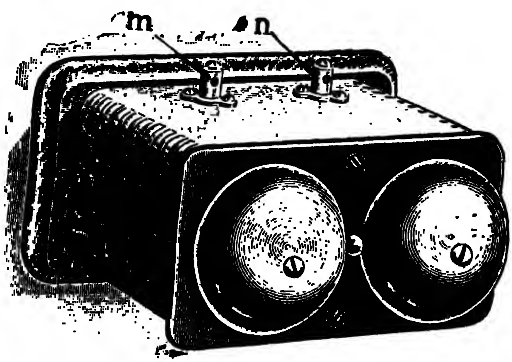


FIG. 48.—An Extension Bell for a Bridging Station

The line wires *m* and *n* are brought to the connecting rack *r*, on which is usually mounted the induction coil *a c*. The primary winding of this coil is denoted by *a*, and the secondary winding by *c*. The battery *b* is generally placed near *r*, and the desk set, comprising the telephone stand *s*, and the box *d* containing a magneto bell and generator, is placed where desired, the telephone on the desk, and the box screwed either under it or at its side.

Three-wire twisted conductors, each of No. 18 B. & S. gage rubber-covered wire, join the binding posts 1, 3, and 5 on the rack to the respective binding posts 1, 3, and 5 on the telephone stand. The magneto box may be connected to the line wires either

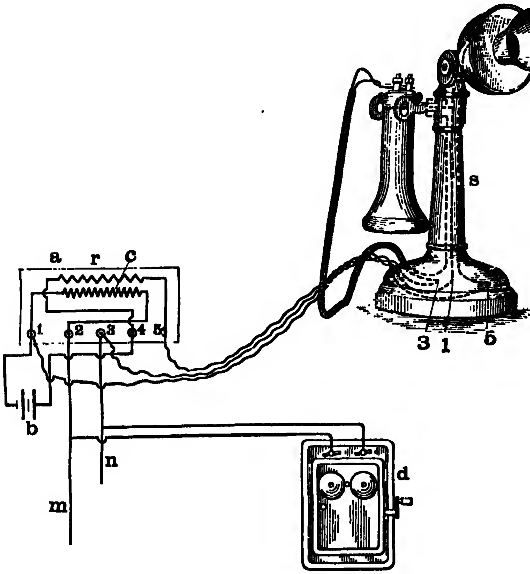


FIG. 49.—The Wiring and Connections for a Desk Set

with straight or twisted conductors of No. 18 B. & S. gage rubber-covered wire.

Modifications of the Bridging Connections are numerous. One of the commonest is that in which the bell and generator, instead of being in parallel with each other across the line, are joined in series and bridged across the line as in Fig. 50. The

generator *g* is then provided with an automatic shunt, Fig. 29, and consequently offers no resistance to the incoming signaling current when not in service. The magneto bell *b* being constructed the same as in Fig. 44, presents sufficient impedance, however, to prevent the talking current being shunted through this path.

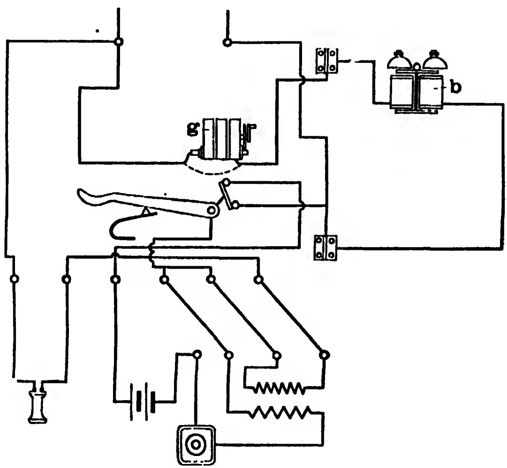


FIG. 50.—Bridging Connection with the Bell and Generator in Series

Other modifications are shown in Fig. 51, where *o* is the battery, *t* the transmitter, *p* the primary of the induction coil, *s* the secondary of the induction coil, *r* the receiver, *g* the magneto generator, *b* the ringer, *m* and *n* the line terminals, and *e* the ground terminal. At *A* are given the connections for a bridging station in which the bell and generator are automatically disconnected during conversation.

Although the bell and generator are here shown in series connection across the line, they may be joined in parallel with each other if an open-circuit generator is used, and operated as in Fig. 44. As

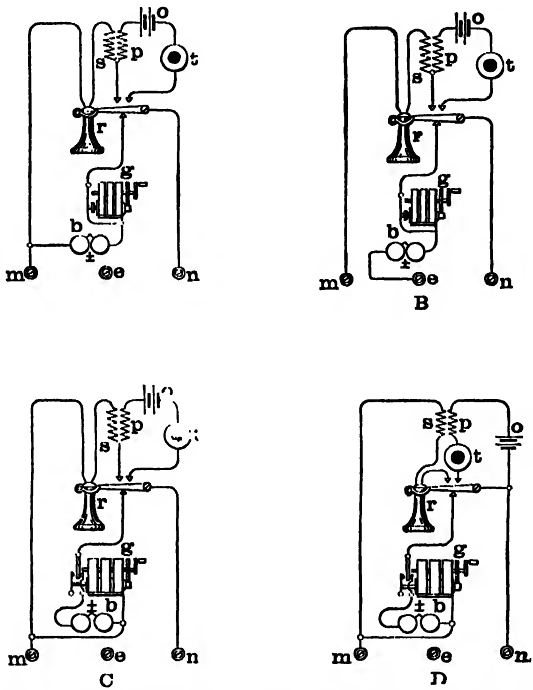


FIG. 51.—Modifications of the Bridging Connection

in previous cases, either a grounded or a complete metallic line circuit can be used. At *B* is shown an arrangement in which the talking circuit is metallic, and the signaling circuit is grounded, the talking circuit or the signaling circuit

being automatically introduced by the action of the hook switch. When the receiver is on the hook the signaling apparatus is in circuit, and when it is off the hook the signaling apparatus is entirely disconnected. At *C* is given a plan of wiring for a wall set, somewhat different from that in Fig. 47, and at *D* is a different form of wiring from that in Fig. 49 for a desk set. The ringers are all of the bridged type. The generators in cases *A* and *B* are provided with automatic shunts, but in the cases *C* and *D* they are of the open-circuit type.

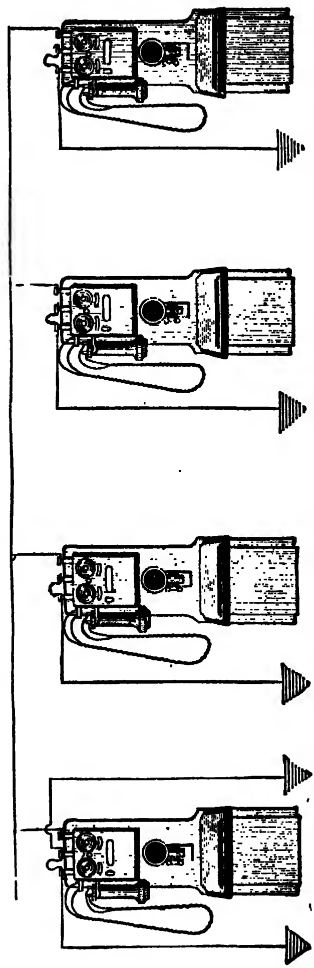


FIG. 52.—Method of Wiring Bridging Telephone Sets on a Grounded Circuit

The Op ration of the Bridging Station.—Bridging stations when operated on a grounded system are connected together as shown in Fig. 52, and when operated on a complete metallic sys-

tem are connected together as in Fig. 53. As previously noted, disturbances are more frequent in grounded systems, but only half as much line wire is required as with complete metallic circuits. The ordinary operation of bridging stations is practically the same as already described for series stations, a party ringing once to signal one station, twice to signal another, and so on, or by a predetermined code of long and short rings accomplishing the same results. As, in the previous case, the line is serviceable for but two parties at a time, there is no privacy afforded the conversation, and the ringing of all the bells simultaneously is somewhat annoying. Notwithstanding these dis-

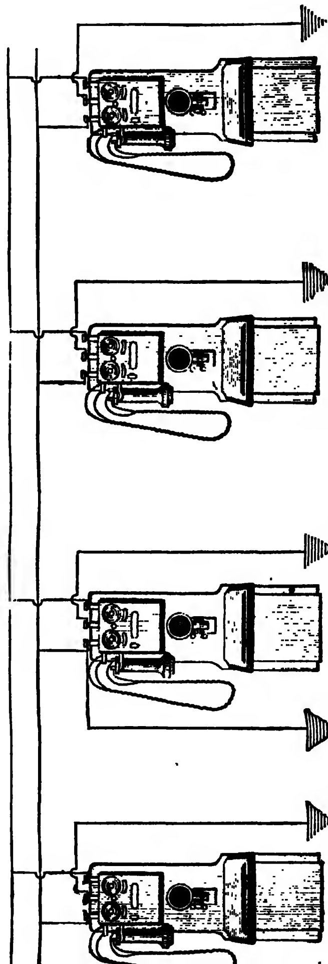


FIG. 53.—Method of Wiring Bridging Telephone Sets on a Complete Metallic Circuit

advantages, both the series and the bridging systems are widely used in small communities, the cost of such installations being materially less than for direct-line service.

It has been estimated that for small business-houses, or where 8 or 10 calls are the daily average, but two stations should be connected on a line; for residences, or where 3 or 4 calls per day are usually made, but 4 stations should be connected; and for certain rural districts, up to 10 or 12 stations are practicable.

The bridging system is preferable to the series system in that the path of the talking current is cleared of the impedance offered by the various bell magnets in the latter case, for when the bells are in series their individual impedances are added together. It is thus possible in the bridging system to have a greater number of stations connected on a line (in certain localities as many as 25 are connected), to operate over much longer distances, and to have far better service than in the series system. On the other hand, bridging bells, which on any one line should all be wound to the same resistance, cost from 25 to 50 per cent. more than series bells, and when many stations are connected 4-magnet generators must be used in place of 3-magnet generators; these increased expenses, however, are small in comparison with the advantages mentioned.

Different Forms of Telephone Sets.—Telephone sets are made up in a great variety of ways; two

of the most common forms are the solid-back wall set and the desk set shown respectively in Figs. 31 and 46. In addition to these a number of other forms are shown in Figs. 54, 55, 56, and 57. Fig. 54 illustrates a cabinet wall set. This set differs from the solid-back wall set, Fig. 31, in having the battery box *b* extended to the floor so that the set is supported upon the floor rather than by the wall. This is desirable in cases where the wall cannot be used for the purpose. The induction coil is mounted in the magneto box *a*, and the battery cells are placed one above the other in *b* instead of side by side as in the solid-back wall set. Fig. 55 shows a hotel or residence set, its compactness being its chief characteristic. At *B* the door of the set is open, showing the box to contain all of the telephone apparatus except the battery, which must be placed elsewhere. The transmitter is placed upon a knuckle joint, which permits of the usual vertical adjustment provided in most sets for conforming to the height of the user. Fig. 56 shows a swinging-

FIG. 54.—Cabinet Wall Set

arm desk set for office use. This set differs considerably from the desk set, Fig. 46; its adjustable

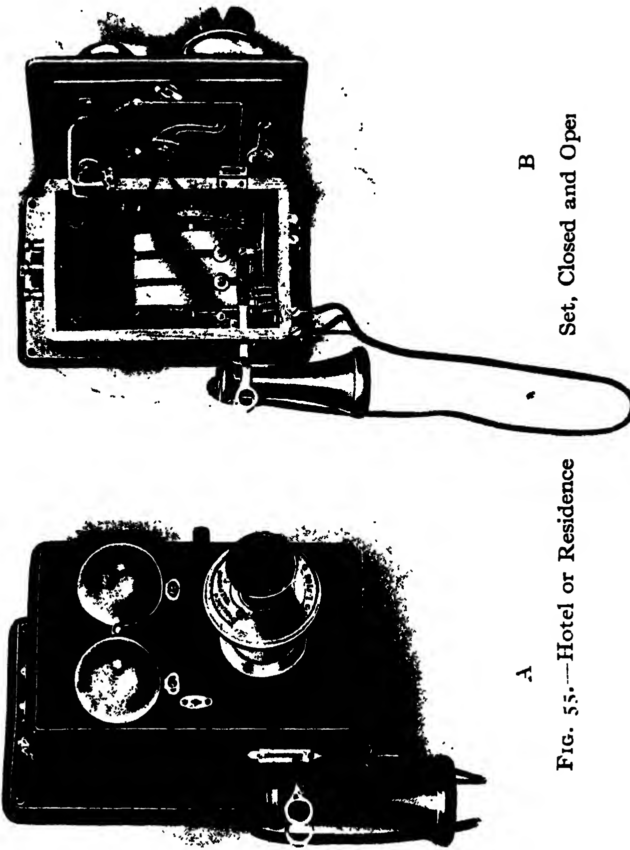


Fig. 55.—Hotel or Residence Set, Closed and Open

arm *a* enables the apparatus to be kept ready for instant use, yet out of the way and securely fast-

ened in place. Fig. 57 shows a desk cabinet set, intended for use where it is desired to sit down in telephoning; this set is especially suited for hotels, business offices, and telephone booths. The transmitter *t* is mounted on an iron arm, and the head of the transmitter is hinged so as to be adjustable. The battery is placed in the box *b* below the writ-

FIG. 56.—Swinging-Arm Desk Set

ing desk *m*, and the rest of the apparatus is mounted in the glass-covered compartment *n*.

Telephone Booths.—These are sound-proof wooden cabinets containing a telephone set and the necessary space for one person in telephoning. They are built with double walls, roof, floor, door, and windows, and have an air space of $\frac{3}{4}$ inch between the inner and outer parts. This air space

deadens or retards the passage of sound from the outside to the inside, or the reverse. Fig. 58 shows the usual form of a telephone booth.

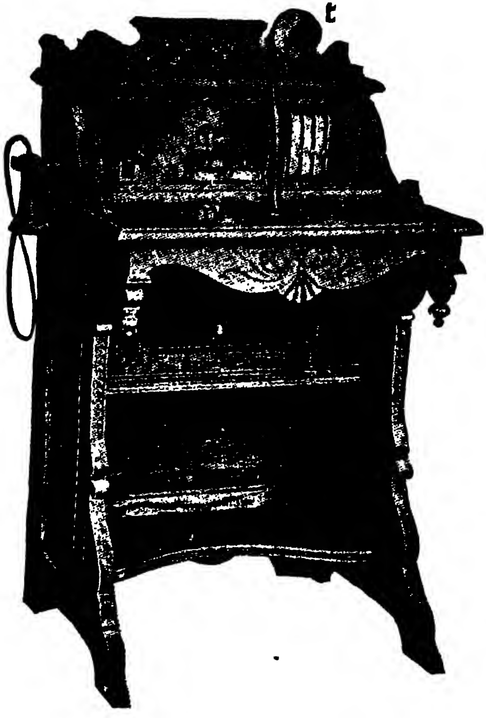


FIG. 57.--Desk Cabinet Set

Fig. 58.—Telephone Booth

INSPECTION AND MAINTENANCE OF TELEPHONE INSTRUMENTS

The Receiver.—Receivers, on account of their location entirely outside the telephone case, are particularly exposed to injury. During the inspection trips, which should be made every three or four months, the receivers should be given special attention. The diaphragm cap should be unscrewed from the body of the receiver, and the diaphragm examined to see if it is bent or rusty; if either of these symptoms show up it should be replaced by a new diaphragm, but if apparently all right it should be dusted and used again. The strength of the permanent magnet should be tested by placing the diaphragm in contact with the pole faces; if a violent shaking of the magnet lengthwise fails to dislodge the diaphragm, the magnet is sufficiently powerful. Another method of testing the magnet consists in seeing if it will hold up the diaphragm by its edge. If the magnet fails to pass either of these tests, a new receiver should be substituted.

In reassembling the parts of the receiver, care

must be taken to have the faces of the magnet exactly $\frac{1}{32}$ inch from the diaphragm. This can be tested with the diaphragm off by placing a small flat stick across the circular support of the diaphragm and measuring the distance between the stick and the pole faces of the magnet. If the magnet is not in its proper position, it must be adjusted by turning it on the screw which holds it to the case. All parts must be perfectly clean when reassembled.

Receiver cords should be tested for a possible break or poor connection by listening in the receiver while the wire cord is moved or twisted; perfect receiver cords with clean bright tips securely connected to the binding posts are necessary for satisfactory operation. The sizzling sound sometimes heard in a receiver results from loose connections or from too strong a talking current rather than to a defect in the receiver.

The Transmitter.—Transmitters are less liable to get out of order than are receivers. Loose connections and too strong or too weak a battery current are often responsible for so-called transmitter troubles. If the current is too strong the carbon in the transmitter will heat, and if granulated carbon is used it will then become packed; on the other hand, too weak a battery current will give a weak transmission. Packing of the carbon granules can usually be overcome temporarily by lightly tapping the side of the transmitter, and permanently by using not more than two Fuller

cells in series or their equivalent in the other forms of cells previously described.

In the Blake transmitter, it is very important that the contact between the platinum ball and carbon button be kept clean and in good condition; otherwise the sound will be scratchy. As the platinum ball by pressing against the carbon tends to roughen it, the latter should be rubbed occasionally with emery cloth and polished with a clean piece of paper. The platinum ball should also be polished, using unglazed writing-paper for the purpose. The springs must be left tightly clamped to their supports, and the final adjustments made by the bottom screw. If the sound is hollow the diaphragm should be given more play by loosening up the damper, and if there is a metallic pitch to the sound the diaphragm is probably bent.

The solid-back transmitter seldom requires attention. At times, however, the nuts at *y*, Fig. 11, binding the diaphragm at its center to the inner metal cone become loosened and have to be tightened, because the vibrations of the diaphragm are not then perfectly transmitted to the carbon, and the sounds are more or less indistinct. To tighten the nuts it is necessary to remove the metal cover *r r* from the case *s* by unfastening the screws around the outer edge. The nuts can then be loosened and the diaphragm adjusted to its proper place, after which the nuts may be tightened and the parts reassembled. If the diaphragm has been injured in any way, it is reached by following the instruc-

tions just given, and should be replaced with a new one.

Poor transmission of speech is not always due to a defect in the transmitting devices. It may be caused by an improper use of the telephone as indicated in Fig. 59; in such a case the transmission will be indistinct and weak, no matter how good the transmitter and the other apparatus. Holding the transmitter against the breast as has

FIG. 59.

FIG. 60.

FIG. 59.—Improper Position in Telephoning
FIG. 60.—Proper Position in Telephoning

recently been advocated by some medical authorities, instead of in front of the lips, may have its advantages from a hygienic point of view, but the voice is not transmitted as clearly nor as well because in the former case the vibrations of the larynx must travel a comparatively long, obstructed route through the lungs, thoracic walls, and garments of the user instead of through a short free-air space in the latter case. Fig. 60 shows the proper way to use the transmitter in talking, to secure the best results.

The Battery.—*Battery troubles generally arise from an exhausted battery solution, insufficiency* of zinc, inferior quality of the plates, or from poor connections with the plates. An exhausted battery solution in the Leclanché cell is indicated by crystals collecting on the zinc; in the Fuller cell, by the color of the liquid becoming dark; and in the gravity cell, by the position of the dividing line between the two solutions being too high or too low. The dividing line should be kept about 1 inch above the copper plate either by replacing a portion of the zinc sulphate with water or by introducing more copper-sulphate crystals; *the addition of the water will cause the dividing line to drop, and the addition of the crystals will cause it to rise.* Dry cells become exhausted in from six months to a year and a half, depending upon how much the telephone is used; when they have become exhausted they should be replaced by new ones. During their useful life they require practically no tantetion. Porous cups in batteries should be renewed when they take on a rusty color.

Battery zincs require as much attention as the solution. When they become coated with salt, it is necessary to scrape and thoroughly clean them; if they have been much eaten away, new ones should be substituted. In purchasing new zincs, it is advisable to select only those having a light color and which give no indications of being porous, as they are then less liable to certain impurities. If the zincs are not amalgamated when purchased,

this should be done by first cleaning them in sulphuric acid and then rubbing mercury over their surface. Copper plates after much usage become so filled with salt that their effective surface is considerably lessened, they should then be replaced by new ones.

The terminal connections of the battery must be kept tightly screwed and free from creeping salts. The contact surfaces should be made clean and bright before they are placed together. *In connecting a wire to a binding post it should be bent around the screw as at A, Fig. 61, so that the nut when being screwed on will tend to draw the wire closer to the screw and not throw it out as it would if the wire be bent as at B.*

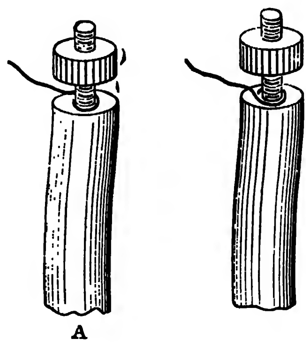


FIG. 61.—Right and Wrong Ways of Connecting a Wire to a Binding Post

Although a defective battery may usually be remedied by treating the apparent trouble, the exact working conditions of a cell can best be learned by testing its voltage with a low-reading voltmeter, Fig. 62. Comparing the reading on the scale *a* when the terminals of the cell are disconnected from the telephone circuit and joined by short wires to the binding posts *c* and *s* of the meter, with

the figures previously given for the electromotive force of the kind of cell tested, will show the true operating condition of the cell. A battery is often exhausted unnecessarily by the user of the telephone forgetting to replace the receiver on the hook switch when through talking. This leaves the battery circuit closed through the transmitter and primary winding of the induction coil, and makes the cells work continuously.

The Magneto Bell.—A thorough inspection of the magneto bell necessitates the door of the magneto box being opened and an examination made of the movement of the clapper. If the clapper clings to one gong, that gong should be moved slightly toward the other gong and against the clapper. If the ring is not loud and clear, it indicates that the gongs are too close together. They should be so adjusted that the clapper just touches their edges when in its extreme positions. The soldered connections in the bell circuit on the door and hinges should also be carefully examined.

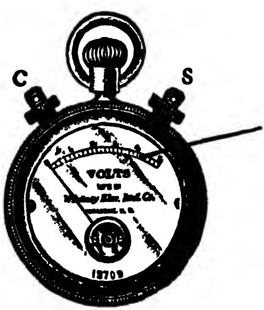


Fig. 62.—A Low-Reading Pocket Voltmeter for Testing Battery Cells

The Magneto Generator.—Defects in generators can usually be traced to their circuit-closing devices. In series generators the spring of the auto-

matic shunt is usually the cause of the trouble; in bridging generators, the contact between the armature shaft and contact spring is often defective by reason of dust and oil accumulating thereon. A slight bending of the spring, or perhaps a new one, will be required in the former case, and the cleaning of the contact surfaces will be necessary in the latter case, to set matters right. If platinum contacts are used, unglazed writing-paper should be employed to clean them; otherwise emery cloth or sand-paper may be used. Occasionally, the permanent horseshoe magnets become weakened, preventing the development of current. This can easily be tested by placing the fingers across the terminals of the generator and turning the handle. If no shock is felt with the contacts and springs in good condition, the magnets are at fault and a new generator should be put in. An occasional oiling of the gear wheels and armature bearings is necessary to make them run smoothly.

The Hook Switch.—This part of a telephone set sometimes fails by making poor connections with the contact springs. In a series set, the trouble is usually in the contact with the lower spring, in which case the bell circuit will be open when the receiver is on the hook. In a bridging set, accumulations of dust on the springs actuated by the hook switch may cause poor contacts between the springs, or they may have become slightly bent out of shape. A slight bending of the springs and

the use of unglazed writing-paper or fine sandpaper are the remedies to apply.

To Locate Trouble in a telephone station without examining each part of the apparatus separately, the inspector should proceed as follows. If the trouble is in the signaling circuit and is such that the station can be called but cannot call others, the magneto generator should first be tested. This, in case of a series set, should be done by connecting together the top binding posts of the set and turning the handle of the generator; if the bell of the set rings, the generator is all right; but if it does not ring, the generator must be examined for the defects previously suggested. In case the bell rings, the short-circuiting wire should be removed from across the top binding posts of the set and placed across the line circuit at the point of entrance to the building. The ringing of the bell now indicates that the inside wiring is all right and that the trouble is elsewhere. The ground connections might then advantageously be inspected. In case of a bridging connection, the generator, if in good order, should ring the bell of the set without any changes being made in the wiring. If it does not ring its bell, an examination should be made of the generator; but if it can do this, an inspection is necessary of the other ringers on the line to see if all of them have the same resistance.

If the station cannot be called but can call others, the bell should first be examined; in case

of a bridging bell, the generator of the set should also be inspected for a short circuit between its contact spring and the insulated pin on its armature shaft, and the resistance of the ringers on the line should be checked up.

If the trouble is in the talking circuit and is such that a message can be received but not transmitted, the battery would first be suspected; next a broken connection in the battery circuit; and finally, a damaged transmitter.

If a message can be transmitted but not received, the fault is obviously in the receiver. Weak incoming messages and signals, however, may be due to poor connections.

The Inspector's Kit should contain a screwdriver, tack hammer, file, pair of long-nosed pliers, pair of cutting pliers, trimming knife, soldering lamp and iron, solder and soldering fluid, roll of rubber tape, coil of No. 18 insulated wire, small bottle of machine oil, dust brush, candle, small low-reading voltmeter, chamois skin, cloth, and oil or paste for polishing outside of telephone set, fine sand-paper, emery cloth and unglazed writing-paper, box of nuts, screws, staples, and washers, box of granulated carbon, box of carbon buttons, receiver and transmitter diaphragms, receiver cords, magneto-box hinges, rubber bands, dampers, and contact springs. In a separate bag should be the battery supplies, comprising zincs, carbons, copper plates, porous cups, solution ingredients, or dry cells, depending upon the kind of batteries in

use. Some cotton rags or waste, and a sponge, should be included if wet cells are employed. Glass battery jars cannot well be carried with the other materials, and if any of those in use are found to be broken or cracked, a separate trip should be made.

TELEPHONE LINE WIRING

The Route to be taken by the telephone lines is governed by the location of the stations to be connected, and by the streets, roads, or alleys along which rights of way can be obtained. The shorter the line and the straighter its course, the better. Rights of way must generally be secured by dealing individually with each property owner on whose land poles are to be placed. The agreements thus made should be in writing and should state with reference to a sketch the number and location of poles to be erected, braced or guyed, and the extent to which tree-trimming can be carried. These matters should be settled definitely before beginning the construction of the pole line.

The Pole Line consists of poles set in line along the route chosen. Each pole carries one or more cross-arms or brackets near its top, and each cross-arm usually carries from 6 to 10 glass insulators supported on wooden pins. The line wires are tied to the insulators and run parallel with each other from pole to pole. When the line consists of less than 6 wires, brackets fastened to the sides of the poles are generally used in place of cross-arms for supporting the insulators. When the

line consists of more than 15 complete circuits, that is, more than 3 10-pin cross-arms can carry, a 50-pair cable is suspended between the poles, and the cross-arms are used for further growth.

The Location of the Poles according to the right-of-way agreements should at first be indicated by stakes driven in the ground at uniformly equal distances of 130 feet. This spacing will require 40 poles per mile of line. At curves and at railway and stream crossings, however, the spacing may have to vary so as to conform to the existing conditions and afford the proper strength and alignment. Along railway lines the poles should not be set within 7 feet of the edge of the rails, and the line wire must be at least 22 feet above the top of the rails. In crossing roads, streets, or highways the vertical distance between ground and wire should be at least 18 feet, and the crossing should be made at an angle of 45 degrees.

In crossing hilly country the shortest poles should be used on high ground and the longest poles in the valleys, as in Fig. 63. The intermediate poles should be of such lengths that the difference in height between adjacent ones will not tend to lift any of the insulators off their pins; in Fig. 64 such a tendency exists at *a*. The smoothest and best proportioned poles should be reserved for use in front of residences, and the heaviest poles for the corners and curves.

Telephone Poles.—Chestnut, southern cedar, and Norway pine are the woods now chiefly used for

telephone poles. The timber should be cut in the winter months, from December to February, when the sap has left the trees and growth is temporarily suspended. The presence of sap in a

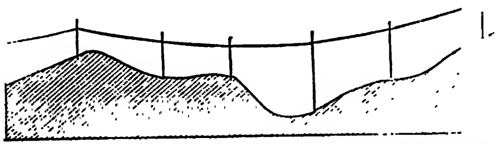


FIG. 63.—Proper Distribution of Poles in Hilly Country

pole causes it to rot quickly. Each pole should have not more than one bend nor a sweep of over 12 inches; it should be closely grained, free from large knots, and its heart must be sound and firm. The bark and branches should be removed and the pole cut to the required length as soon after it has been felled as possible. The required length depends upon the number of cross-arms it must

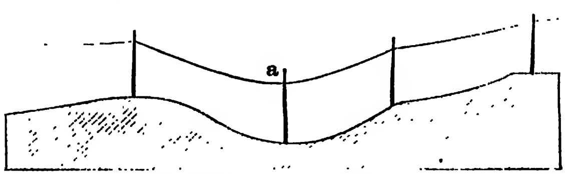


FIG. 64.—When Poles All of the Same Lengths are Used in Hilly Country, Some of the Insulators May be Lifted Off their Pins

carry and the obstacles to be cleared by the wires. With 1 cross-arm, the pole must be at least 15 feet above ground and at least 5 feet in the earth, so 20-foot poles are the shortest ones practica-

ble. Longer poles usually vary by 5 feet upward to 70 feet and are buried from 6 to 8 feet in the earth. The circumference at the top of the pole and at 6 feet from the butt must be considered in selecting poles. These dimensions should be proportional to the length of the pole and should approximate those given in the following table for poles from 20 to 70 feet long:

Length of Pole, in Feet	Circumference at Top, in Inches	Circumference Six Feet from Butt, in Inches	Approximate Weight per Pole, in Pounds	Depth in Feet to which Pole Should be Buried
20	13	24	100	5
25	19	27	350	5½
30	22	34	450	5½
35	25	40	600	6
40	25	43	800	6
45	25	46	1,000	6½
50	25	50	1,250	7
55	25	54	1,550	8
60	25	58	2,000	8
65	22	58	2,700	8
70	22	64	3,400	8

The top of each pole should be slightly pointed as in Fig. 65 and then painted to enable it to shed water. A number of gains *n* should be cut in the pole, corresponding to the number of cross-arms to be used. The center of the first gain should be 10 inches from the top of the pole, and the center of each subsequent cut should be 24 inches below that of the preceding one. The gains should each be 3¾ inches wide and ½ inch deep, true and square with the axis of the pole so that the

cross-arms when fitted in them will be at right angles to the pole in all directions. Each gain should be bored for one $\frac{5}{8}$-inch bolt, directly through the center of the pole and at right angles to the gain, and should be painted to protect it from moisture. A paint well adapted for the top and gains of a pole is Prince's metallic paint, mixed in the proportion of 7 pounds of the dry paint to

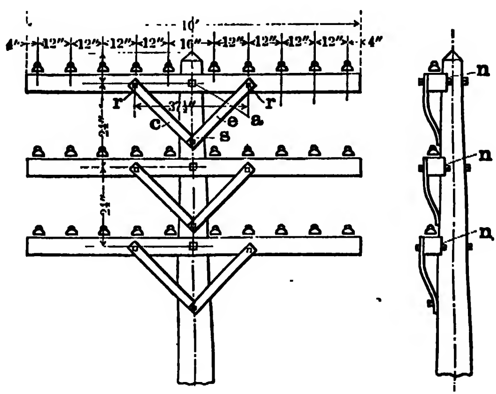


FIG. 65.—Telephone Pole Top Equipped with Cross Arms, Braces, Pins, and Insulators

1 gallon of linseed oil. Two thick coats of this paint should be applied.

In Setting Poles a hole for each one is dug in the ground to a depth of 5 to 8 feet, depending on the height of the pole and the condition of the ground. When the ground is of normal consistency, the depths noted in the table just given are considered proper for straight lines; on corners

and curves the strain is greater, requiring ½ foot greater depths than tabulated. The hole should be dug large enough to allow the pole to be dropped straight in without forcing it. Poles less than 45 feet in length are raised as shown in Fig. 66. This generally requires about 6 men, 4 of whom are provided with pike poles *m*, *n*, *r*, and *s*, that is, wooden poles from 8 to 14 feet long terminating

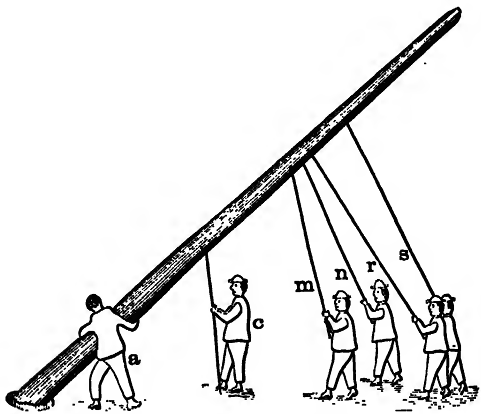


FIG. 66.—Method of Raising a Telephone Pole

in sharp iron points. The 4 men are distributed around the telephone pole which is placed with its butt projecting over the hole dug for it, and, by sticking their pikes in the pole and pushing, raise it to an upright position in the hole. The fifth man *a*, standing at the hole, guides the butt of the pole in the proper direction, while the sixth man *c*, with a heavy pole terminating in a U-shaped iron prong called the dead man, steadies the pole as it

is being raised. Poles over 45 feet long are raised by means of a tripod-derrick erected over the hole.

The pole must be given its proper position in the hole before the earth is packed around it. In straight lines the pole must be placed perpendicular; at curves, it should be inclined slightly outward to compensate for the pull of the wires. The poles must be turned so that the gains for the cross-arms on consecutive poles come on alternate sides; this will lessen the number of cross-arms liable to be pulled off in case of a pole breaking. On straight lines the gains should be perpendicular to the line, and on curves they should be set radially. While the pole is held in its proper position the open space in the hole is filled in by means of one shovel, the earth being packed solidly around the pole by the simultaneous use of three tampers. Coarse earth or gravel should preferably be used at the top of the hole. When the ground is sandy or marshy a 6- or 8-inch grouting composed of 1 part Portland cement and 2 parts of sand mixed with broken stone may well be used as an artificial foundation.

Side Strains on Poles at curves and corners must be counterbalanced by means of guys or braces. For guys, galvanized steel cable composed of not less than 7 strands, each 0.109 inch in diameter, must be used. One end of this should be fastened to an iron rod *a*, Fig. 67, about 8 feet long, which is threaded at the lower end and provided with a nut and washer *s*. This rod is passed through a

plank *m* and log *c*, the latter about 5 feet long and not less than 8 inches in diameter, and then buried

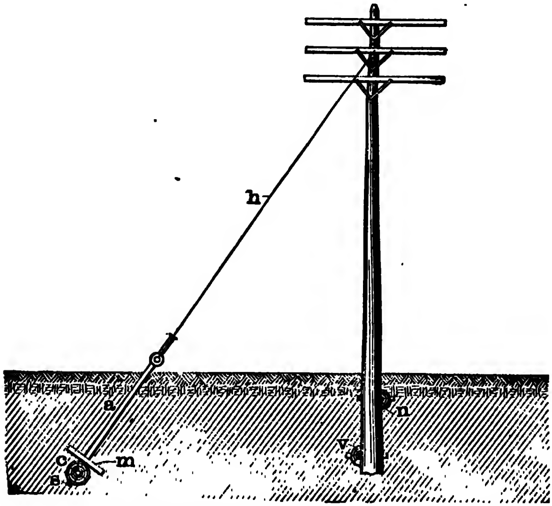


FIG. 67.—Method of Guying a Telephone Pole

6 feet under ground in such a position with respect to the pole that it will lie in the direction of the

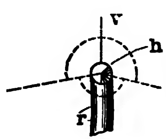


FIG. 68.—Plan of Pole Line, Showing the Proper Position of a Guy and a Brace for Counterbalancing the Side Strains on a Pole

guy *h*, and make the plank and log serve as an anchor. The butt of the pole to be guyed should

be reinforced with 2 logs *n* and *v* similar to the one just mentioned, bolted to the butt of the pole as shown. The greater the distance between the butt of the pole and the anchor log *c*, the more

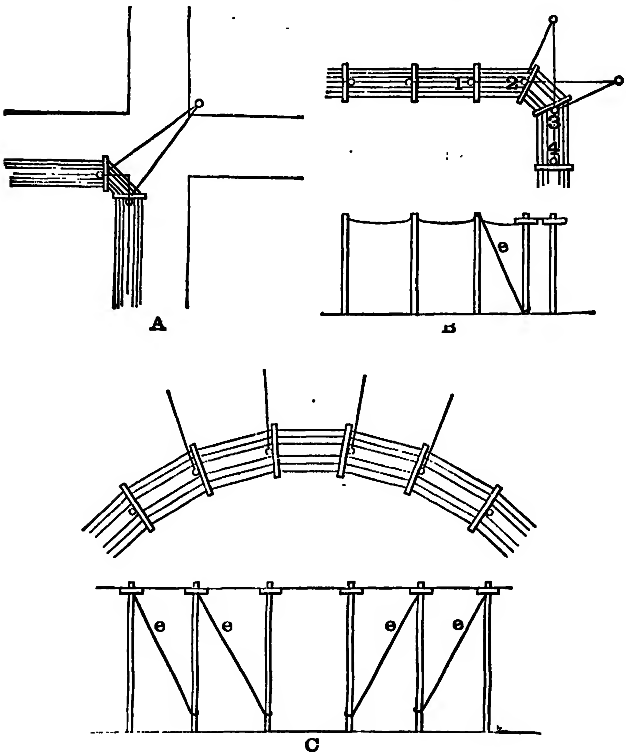


FIG. 69.—Details of Guying at Corners and Curves

serviceable the guy. In all cases the guy should halve the obtuse or outside angle formed by the poles. Thus in Fig. 68, the position of the pole *h*

causes the line to curve at this point. The strain of the wires from the poles *c* and *e* tends to pull the pole *h* toward the observer, and to counterbalance this the guy *v* should exert a tension in the opposite direction, along the bisector of the obtuse angle *c h e*. Some practical applications of guys at corners and curves are shown in Fig. 69 at *A*, *B*, and *C*. Head guys *e*, etc., are needed in case *B* from top

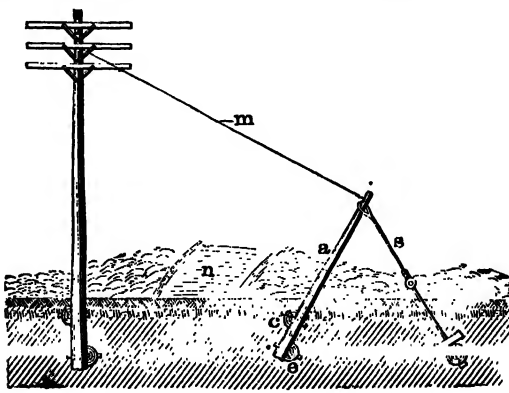


Fig. 70.—Use of a Guy Stub for Clearing Obstacles

of pole 1 to bottom of pole 2 and from top of pole 4 to bottom of pole 3. In case *C*, head guys *e* are used toward the middle of the curves as shown. The guy cable should be fastened to the pole by wrapping it twice around and then clamping it. Staples are used to prevent the guy from slipping on the pole.

Guy stubs serve to raise the cable when it is desired to clear obstacles. Thus, in Fig. 70 the guy stub *a* permits the pole guy *m* to be carried

sufficiently high to permit the use of the path *n*. The anchor guy *s* is fastened to *a* about 3 inches below *m*, and both *s* and *m* are held in place by staples. The guy stub should be strengthened by 2 logs *c* and *e* as shown.

Trees are sometimes convenient for anchors, but when thus used should be protected with lagging of boards or staves placed around the tree where the guy cable is wrapped. No limbs under 5 inches in diameter should ever be used for anchors; in any case the trunk of the tree is preferable.

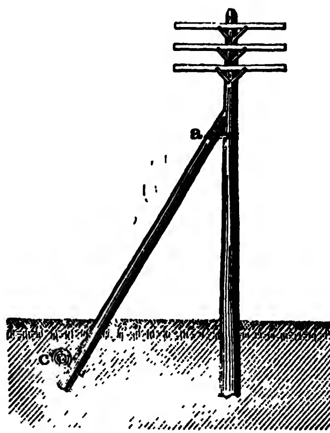


Fig. 71.—Method of Bracing a Telephone Pole

Pole braces are used where it is impracticable to use a guy. These are placed so as to halve the acute or inside angle formed by the poles. For example, in Fig. 68 the brace *r*, consisting of a pole similar to the telephone pole, is placed as shown and serves the same purpose as the guy cable *v* in counterbalancing the side strain upon *h*. Fig. 71 shows the method of installing a brace. It is bolted at the lower end to an anchor log *c* buried 6 feet below the surface, and the other end is secured to the telephone pole by means of 2 nails

driven through the 2 poles and by No. 6 iron wire *a* wrapped 3 times around the poles and held in place on the brace by a 5-inch fetter drive screw.

Pole Brackets.—These may be used in place of cross-arms for supporting telephone wires when the pole is not to contain over 6 wires. In this case no gains need be cut on the pole, as the brackets are screwed directly to the sides of the poles. Wooden brackets, *A*, Fig. 72, are generally used where the pole is to carry 1 or 2 wires, and iron brackets, *B*, Fig. 72, for more than 2 wires. Where more than 1 bracket is needed, they are placed on opposite sides of the pole so that there is the same number of wires on both sides.

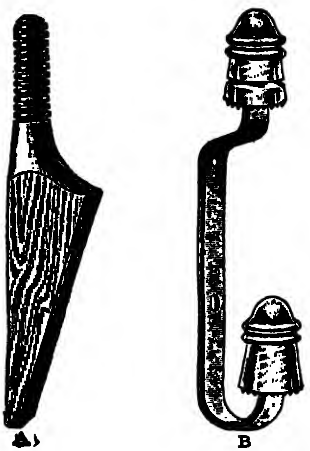


FIG. 72.—Pole Brackets

The lineman climbs the pole after it is set, by means of spurs strapped to his legs, and fastens the brackets in place with drive screws.

Cross-Arms.—If cross-arms are to be used they should be bolted in the gains cut for them on the poles, after the poles are in position. The lineman carries with him up the pole a pulley and a coil of rope. The pulley he fastens to the top of the pole and then passes the rope through it, allow-

ing both ends to reach the ground. His assistant ties the cross-arm to one end of the rope and by pulling the other end raises the cross-arm to the lineman, who fastens it in place as shown in Fig. 65 at *a*, using a $\frac{5}{8}$-inch machine bolt, nut, and square washers. Two cross-arm braces *c* and *e*, Fig. 65, of $\frac{1}{4}$-inch galvanized steel, each 28 inches in length and 1 inch in width, are also attached to each cross-arm by a 4-inch carriage bolt *r*, and together are secured to the pole by one $\frac{5}{8}$-inch fetter drive screw *s*.

All cross-arms should be made of thoroughly seasoned straight-grained yellow pine. The wood should be solid, free from cracks, knots, sap wood, and dry rot. The principal dimensions are given in the following table. The finished measurements are $3\frac{1}{4}$ by $4\frac{1}{4}$ inches. The pin holes should be such as to afford a driving fit for the pins, and the central hole for the $\frac{5}{8}$-inch machine bolt should be $\frac{11}{16}$-inch in diameter. Cross-arms should be rounded at the top to shed water, and well painted with lead and oil before being placed in position.

Number of Pins per Cross-Arm	Length of Cross-Arm in Feet	Pin Spacing in Inches		
		Ends	Sides	Centers
6	6	4	12	16
8	10	4	15	22
10	10	4	12	16

Cross-Arm Pins.—These are made of locust, and in straight-line construction have the form and

dimensions shown in Fig. 73. The shank *b* fits into the hole in the cross-arm, and is held by a 6-penny wire nail driven through the side of the arm; the flange *d* prevents water from entering the hole. The screw threads at *a* are cut to fit the threads of a glass insulator which screws on the pin. The pin, Fig. 73, is used in supporting but one line and is called a line pin. There is another kind called a transposition pin which is used for supporting 2 lines; this pin differs from that shown only in having the thread cut $\frac{3}{8}$-inch longer.

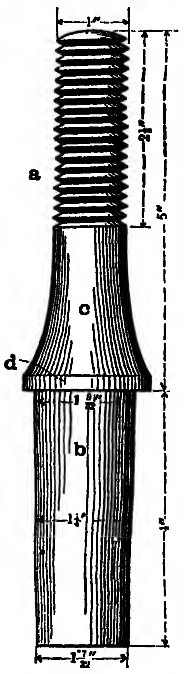


FIG. 73.—A Cross-arm Pin

Insulators.—Insulators for the cross-arm pins are made of glass in two forms: line insulators to fit line pins, and transposition insulators to fit transposition pins. One of the former kind is shown at *A*, Fig. 74, and one of the latter at *B*, Fig. 74. It will be noted the simple insulator has but one groove for wire and is made in one piece, whereas the transposition insulator is made in two pieces in each of which there is a groove for a wire. In placing a transposition insulator on a pin the lower glass is first screwed on so that about 1 inch of the thread of the pin projects through the hole. The upper

glass is then screwed down tightly on the lower half.

Telephone Line Wire.—Galvanized iron wire and copper wire are both used for telephone-line conductors. Iron is stronger and cheaper than copper, but offers nearly six times as much resistance to a current of electricity. Iron line wire is always galvanized to prevent it from rusting, but even the best galvanizing fails to prevent corrosion entirely,

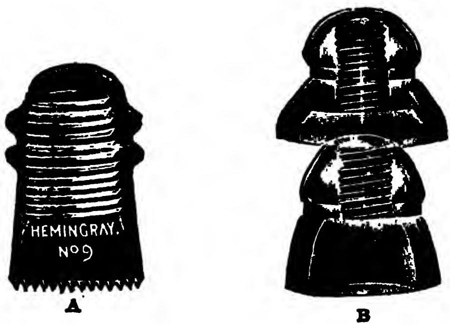


FIG. 74.—Line and Transposition Insulators

in consequence of which iron wire will usually serve less than half the time of copper wire. On the other hand, iron wire costs but 30 cents per pound, whereas copper wire costs about 15 cents per pound. For a private line it is usual practice to use No. 12 galvanized iron wire; for bridging lines not over 25 miles in length, No. 12 galvanized iron wire; and for longer lines No. 10 or No. 8 galvanized iron wire. When copper wire is employed, sizes from No. 8 to No. 14 are used; the No. 12,

having a diameter of 0.08 inch and a breaking strength of about 325 pounds, being the most usual.

For a common return wire used in place of the ground when there are a number of instruments connected together, a No. 8 copper wire is desirable. This usually affords best protection from foreign noises when not grounded. Telephone connection by means of a common return conductor is cheaper than the use of complete metallic lines, but does not afford such freedom from inductive disturbances.

Copper line wire should be hard drawn, uninsulated, and have a conductivity of at least 97 per cent. that of pure copper. Iron line wire should be thoroughly annealed and double galvanized. Iron wire is made in several varieties commonly known as "Extra Best Best," "Best Best," and "Steel." "Extra Best Best" or "E. B. B." wire is made of the very best material and has the highest conductivity of any iron; its breaking strength is about 2.7 times its weight per mile. "Best Best" or "B. B." wire is harder than the "E. B. B." and of less conductivity, but is stronger; its breaking strength is 3.3 times its weight per mile. "Steel" wire is stronger than those previously mentioned, but has poor conductivity; it has a breaking strength of about 4.5 times its weight per mile. The properties of both copper and iron wires are recorded in tables in the Appendix.

Stringing the Line Wires is usually done by aid

of a running board and rope and a team of horses. The rope is carried over the cross-arms of the poles for a distance of about 1,500 feet and its end fastened through the center hole *c* of the running board, Fig. 75. At this end of the line are mounted the reels containing the wires, and one end of each wire is fastened to the board through the holes *a*, *e*, *s*, *n*, etc. The horses are then hitched to the other end of the rope and started, and as they walk away they pull the board and wires over the cross-arms. On each pole a lineman guides the board and wires over the cross-arm, and when the reels

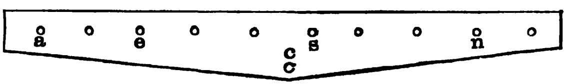


FIG. 75.—Running Board Used in Stringing Telephone Line Wires

are empty the wires are temporarily fastened and the process repeated with full reels until the entire course is covered. In stringing wires over cross-arms below the top one, a divided running board is used, one half of it passing each side of the pole.

In case but one or two line wires are to be strung, the running board and team may be dispensed with, the running rope being then tied directly to a wire and pulled over as many cross-arms as possible by hand.

The line wires are finally drawn tight by means of clamps and tackle, Fig. 76, until the sag in inches between the adjacent poles corresponds to the figures given in the following table for the tempera-

ture and length of span in feet dealt with. If the wires are drawn tighter than there indicated, they are liable to contract and break in cold weather,

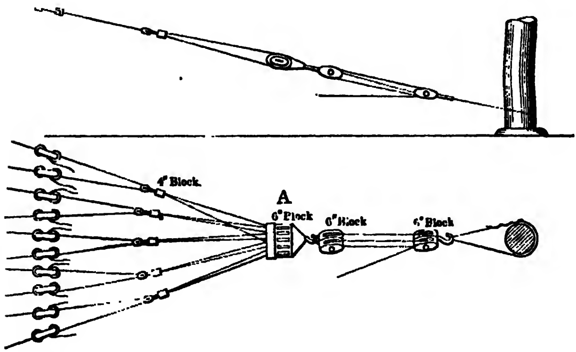


FIG. 76.—Elevation and Plan of Clamps and Tackle Used in Pulling up the Line Wires

and if allowed a greater deflection they will swing in the wind and eventually break at the insulators.

Temperature in Degrees Fahrenheit	Span in Feet					
	75	100	115	130	150	200
	Deflection in Inches					
−30	1	2	2½	3⅜	4½	8
−10	1¼	2½	3	3¾	5	9
10	1½	2⅝	3½	4⅜	5¾	10¼
30	1¾	3	4	5⅛	6¾	12
60	2½	4¼	5½	7	9	15⅜
80	3⅛	5⅜	7	8⅝	11¼	18¼
100	4⅛	7	9	11	14	22¼

Each line wire is tied to its insulator as shown in Fig. 77, the tie wire *m* being from 16" to 22 inches

in length and of the same size and material as the line wire *n n*. On straight lines the line wires are placed on the inner sides of the insulators, excepting the two wires next to the pole, which are placed

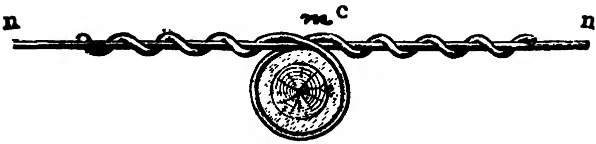


FIG. 77.—Method of Tying the Line Wire to its Insulator

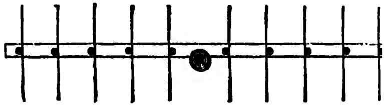


FIG. 78.—Position of the Line Wires on the Insulators in Straight Lines

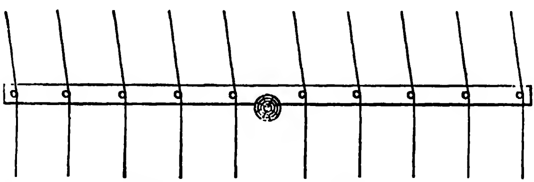


FIG. 79.—Position of the Line Wires on the Insulators at Curves

FIG. 80.—The Standard Western Union Joint for Connecting Iron Wires

outside to afford greater clearance of the pole. On curves, the line wires are placed so that the strain draws them against the insulators. These two cases are shown respectively in Figs. 78 and 79.

Joints in iron wires are made as in Fig. 80, which

shows what is known as the "Standard Western Union" joint. Joints in copper wires are made with McIntire copper sleeves, Fig. 81, each hole in

FIG. 81.—McIntire Sleeve for Connecting Copper Wires

the sleeve being no more than 0.01 inch larger than the wire with which it is used. The ends of the copper wires to be joined are inserted in the respective halves of the sleeve from opposite ends, so that each wire projects one-quarter inch beyond

FIG. 82.—Pliers for Use in Connection with McIntire Sleeves

the sleeve. The ends are then turned over, and by means of McIntire pliers, Fig. 82, the sleeve and wire are twisted as in Fig. 83.

Dead-Ending a copper line wire on its last insu-

FIG. 83.—Copper Wire Joint as Made by a McIntire Sleeve

lator for the purpose of connecting it to a cable or to a station instrument is done as in Fig. 84, the line wire being first slipped through a McIn-

tire half-length sleeve *n*, then wrapped once around the insulator, and finally run back through the sleeve, which is then given one and one-half turns.

Transposing Line Wires.—Telephone instruments are so sensitive that currents induced in the line wires from neighboring circuits produce in the telephones disturbing noises commonly termed "cross talk," unless care is taken to prevent them. To overcome disturbances of this nature, which are especially troublesome in the vicinity of electric-light and power wires, both lines of a telephone circuit must be metallic and balanced with respect to adjacent lines so that the induction from them is neutralized; this balancing is done by transposing the line wires of each telephone circuit on a pole at regular intervals along the line.

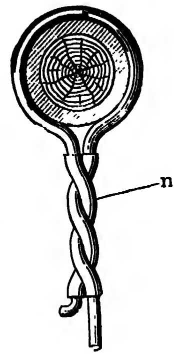


FIG. 84.—Method of Dead-ending a Wire

The method of making the transpositions is shown in Fig. 85. Transposition pins and insulators and McIntire sleeves are employed. Supposing the line wires *m m* and *n n* of a complete metallic circuit are to be transposed, these wires are cut and the two ends of each are dead-ended on the transposition insulator corresponding to that line, the upper groove of the insulator being used for one end and the lower groove for the other end. The four terminals of the two line wires are then

cross-connected by the sleeves *r* and *s* so that instead of *m m* and *n n* being continuous, *m n* and *n m* are continuous.

Four complete metallic circuits *A*, *B*, *C*, and *D*, Fig. 86, have thus been transposed at *a*, *b*, *c*, *d*, etc. Considering, for example, the circuits *A* and *B*, of which *m* and *n* are the conductors of the former and *s* and *r* those of the latter, it is obvious

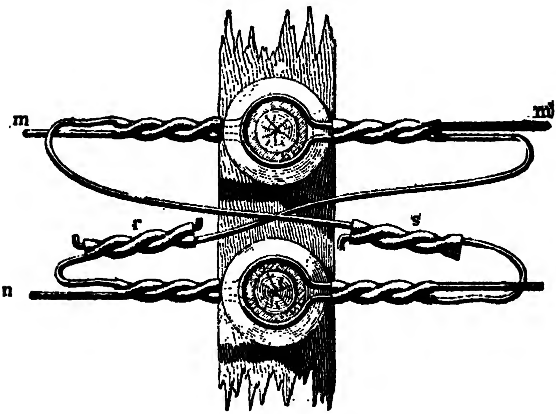


Fig. 85.—Method of Transposing Line Wires

that if a current in *n* induces a current in *s*, the current in the other wire *m* of circuit *A* will induce in *s* a current equal in value and opposite in direction to the first induced current if the transposition *a* be made. The two induced currents will, therefore, neutralize each other, removing the cause of the disturbances, and in the same manner the other transpositions shown will prevent inductive disturbances in the other parts of

the circuit. In circuit *C* the wires should be transposed at about every tenth pole, and in the other circuits transpositions should be made relatively as shown.

In addition to the desirability of thus having both wires of a complete metallic telephone circuit subject to the same amount of inductance, they should also have substantially the same ohmic

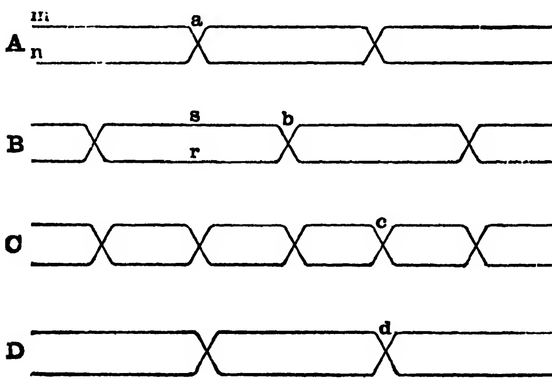


FIG. 86.—Relative Locations of Transpositions in Four Adjacent Circuits

resistance, the same insulation resistance, and the same electrostatic capacity. Aside from the transpositions, both wires should, therefore, be of the same material and of equal lengths, and should be insulated in the same manner on the same cross-arms or in the same cable, and should always be adjacent to each other.

Drop Wires.—The drop wires running from the line to the premises of the telephone user may

consist of a pair of No. 14 B. & S. gage hard-drawn copper wires, tinned, twisted, and insulated either with okonite or with three separate, closely woven braids of cotton impregnated with a moisture-repellent compound. The thickness of the rubber compound in the former case should be $\frac{3}{32}$-inch, and of the furnished cotton insulation in the latter case not less than $\frac{1}{16}$-inch. In place of a twisted pair, however, bare open wires may be used. The drop wires are joined to the line wires as shown in Fig. 87, *A* being the method employed for a series connection, and *B* that for a bridging connection. McIntire sleeves, *c*, are used in the former case, and clamps *s* in the latter case.

Protection.—Pole lines should be protected from lightning by placing on every tenth pole a lightning rod composed of No. 6 galvanized iron wire. This should extend at least 12 inches above the

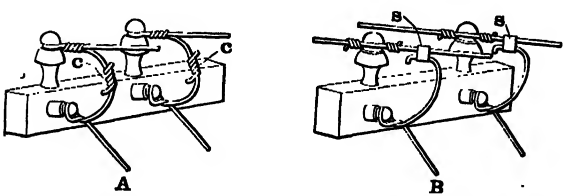


FIG. 87.—Method of Joining Drop Wires to Line Wires in Series and Bridging Connections

pole and be soldered to a ground rod or plate at the base. The wire should run perfectly straight and be fastened to the pole by galvanized-steel staples spaced 1 foot apart.

Poles may be protected from the weather and

at the same time improved in appearance by painting them after the line is finished, with two coats of lead and linseed oil having a dark olive-green color.

Humming of the wires may be prevented by wrapping that portion of them at the insulators with

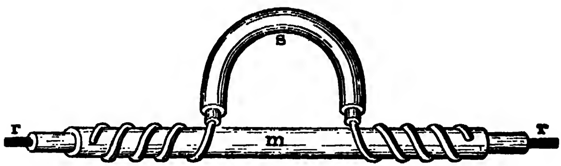


FIG. 88.—Device to Prevent Humming of the Line Wires

soft rubber *r r*, Fig. 88, and over this placing a covering of sheet lead *m*. The tie wire *s* is similarly treated, and the cushion thus formed for the line wire absorbs its vibrations and so does away with the humming.

At curves and corners the line wire at the inner end of a cross-arm may, in case it becomes loosened from its insulator, fall off and, by coming in contact with other wires, do considerable damage. To prevent the wire from falling, an iron guard-arm should be screwed to the cross-arm so as to catch the wire in case of its insulator breaking or its tie wire becoming loosened.

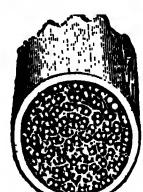


FIG. 89.—A Lead-covered Telephone Cable

Telephone Cables.—These are generally composed of No. 19 B. & S. gage soft-drawn copper wires covered with dry paper and twisted in

pairs, the bunch being encased in a lead sheath about ⅛ inch thick, as shown in Fig. 89. The pairs are twisted to overcome inductance; and to distinguish between the conductors of a pair the insulation on one of them is usually marked in some peculiar way. Specifications for dry-paper cables call

FIG. 90.—Suspension Cable and Clamp Fastened to a Pole for Supporting a Telephone Cable

for a capacity between conductors of not over 0.08 microfarad (see Appendix) per mile; a conductivity of not less than 98 per cent. that of pure copper; an ohmic resistance of not more than 47 ohms per mile at a temperature of 60° F.; and an insulation resistance of each conductor of at least 500 megohms (see Appendix) per mile. Cables

are thus made containing from 5 to 300 pairs of conductors in lengths of 800 and 1,000 feet. A 200-pair cable of No. 19 wires has an outside diameter of only about $2\frac{3}{4}$ inches. Iron wires are never formed into telephone cables.

Stringing the Cable is done by first fixing clamps *n*, Fig. 90, to the sides of the poles a short distance below the cross-arms. A suspension cable *c*, usually composed of 7 strands of galvanized steel wires, is then run from clamp to clamp and bolted in place as indicated. The cable and reel as received from the manufacturer are next mounted at one end of the line, as shown at *m*, Fig. 91, and by means of a manila-hemp rope *r*, Fig. 92, secured to the free end of the cable and led through pulleys *a* temporarily fastened to the poles just below the suspension clamps, and terminating in a windlass *h* mounted at a distance along the line from the reel equal to the length of the cable on the reel, the cable is pulled in position. An iron cap *c*, Fig. 93, screwed to the end of the cable sheath, facilitates the fastening of the pulley rope. The windlass is operated by horse-power as shown. When all the cable on one reel has been strung, the process is repeated, the next reel being set up at the terminus of the first length. Such a case is illustrated in Fig. 91.

Cable Hangers are attached to the cable as the latter is drawn off the reel, and, as the cable is pulled along, the hangers slide over the suspension cable the end of which is temporarily lowered on

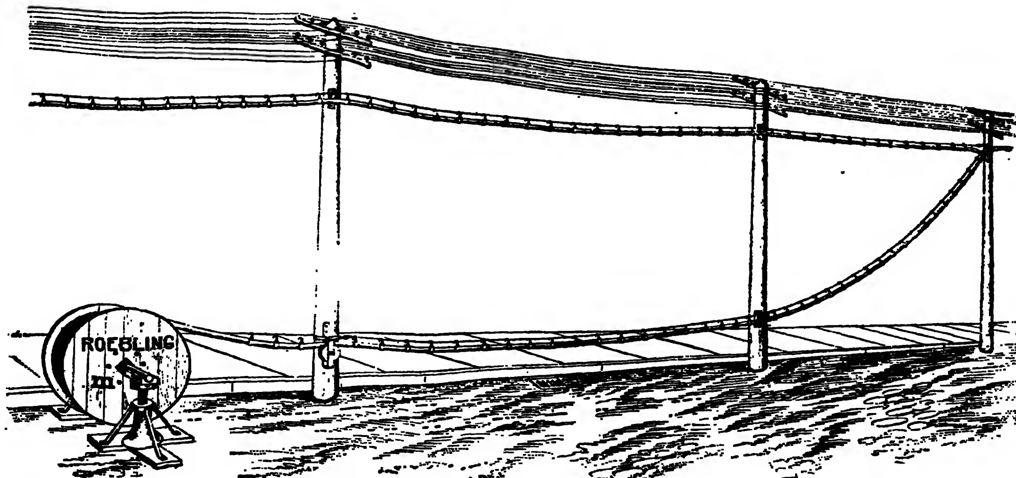


FIG. 91.—Method of Stringing a Telephone Cable, Showing the Mounting of the Cable Reel

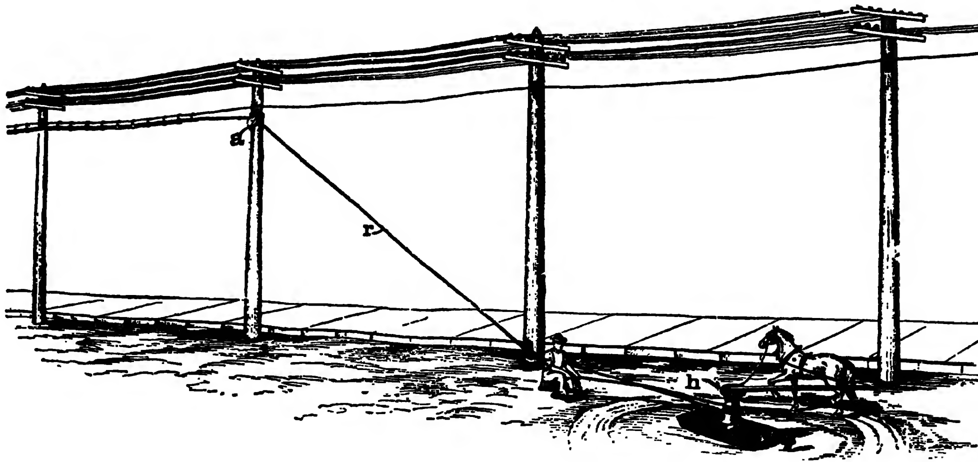


FIG. 92.—Arrangement for Pulling the Cable in Position

a level with the reel as in Fig. 91. One form of cable hanger is shown in Fig. 94 at *a c e*. It consists of a hook and one hemisphere *a*, a vertical

FIG. 93.—A Convenient Device for Fastening the Pulling Rope to the Cable

extension and hemisphere *c*, and a steel ring *e*. The two hemispheres are of galvanized iron; they are placed on each side of the cable *n*, the ring is

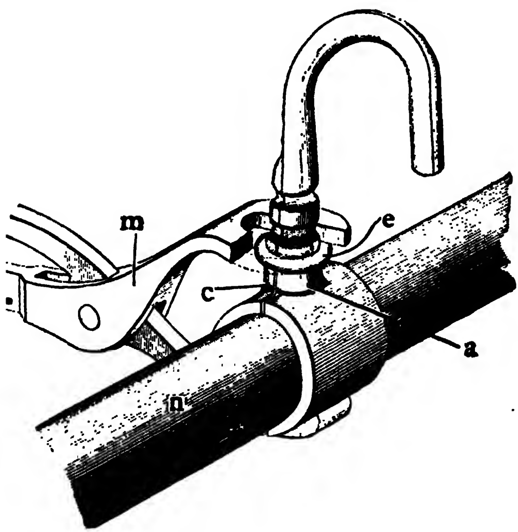


FIG. 94.—A Cable Hanger, and the Tongs Used to Adjust It in Position

slipped down over the hook, and by means of the tongs *m* the ring is forced into place.

Distribution of the wires in a telephone cable is most conveniently accomplished, without moisture entering the cable core, by means of a terminal head, Fig. 95, mounted on a pole as shown at *j* in

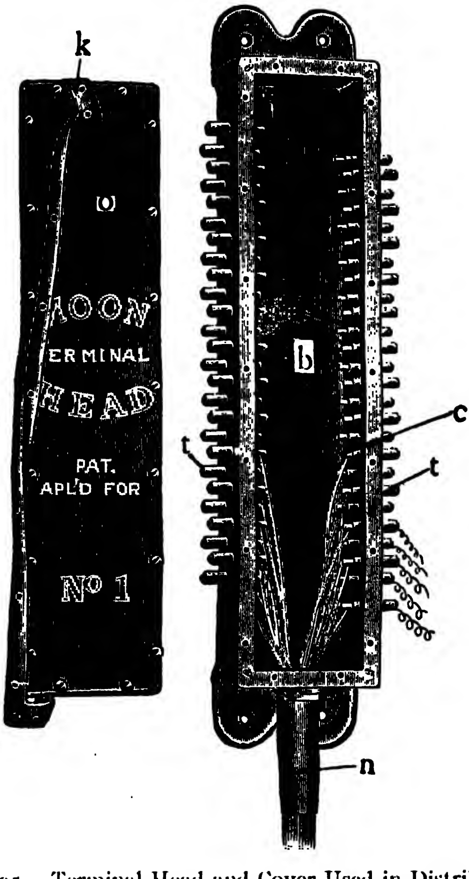


FIG. 95.—Terminal Head and Cover Used in Distributing the Wires of a Telephone Cable

Fig. 96. The pole thus equipped is called a "distributing" or "terminal" pole. An unusually strong pole is selected for this purpose and is placed as nearly as possible in the center of a group of telephone users. A platform *p* is usually provided on the pole to enable the lineman to work easier and quicker. The method of connecting up the terminal head is as follows: The lead seal at the end of the cable, used to prevent the entrance of air and moisture, is stripped off, and the wires are inserted through the nozzle *n*, Fig. 95, allowing the lead sheath of the cable to project within the box *b*. The lead sheath is then connected to the nozzle with a wiped joint of solder, and the ends of the cable wires are soldered to the inside terminals *c*, etc. Moisture is driven out of the box by pouring in, and then pouring out, paraffin heated to about 300°. While the box and wires are still hot, the rubber gasket *k* and cover *o* are placed on the box and screwed tightly in place, leaving the end of the cable hermetically sealed. The outside terminals *t*, *t*, etc., of the box are then connected through short cables *u* and *v*, Fig. 96, with the drop wires *h*, *d*, etc., leading to the telephone users' premises. The dotted lines in Fig. 96 indi-

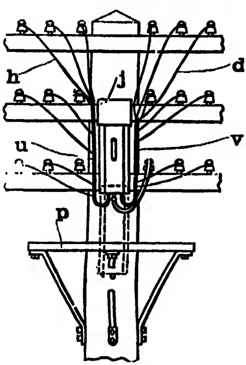


FIG. 96.—Distributing Pole Equipment with a Terminal Head

cate the position of the outer iron cover of the terminal head when pulled down, a runway being provided in the platform *p* to allow the descent of the cover. The terminal head affords, incidentally, a convenient means of altering the arrangement of the circuits when desired, for all that is necessary is to change the cross-connections in the box. Protection from lightning and other strong currents can also be had by using a terminal head fitted with lightning arrester and fuses.

Pole Steps are usually placed on each cable pole; also on all poles more than 50 feet in height, and on all pointed poles. They are made of steel $\frac{5}{8}$ inch in diameter and 10 inches long, turned up at one end and provided with a thread at the other end. These steps are driven on alternate sides of the pole, in line with the cross-arms, and are spaced 18 inches apart on each side.

Splicing cables becomes necessary when the line is greater in length than that of the cable on one reel. Before beginning the process there should be provided a pan containing paraffin, a portable furnace for heating the paraffin to the boiling-point, a ladle, a lead pipe somewhat larger than the outside diameter of the cable and about 2 feet long, called the "lead sleeve," and a paper sleeve about 3 inches long for each joint. First, the paraffin should be heated; then the lead sheaths cut back 12 inches from the ends of the cables to be spliced and the exposed conductors dipped in the boiling paraffin to prevent the paper insulation from

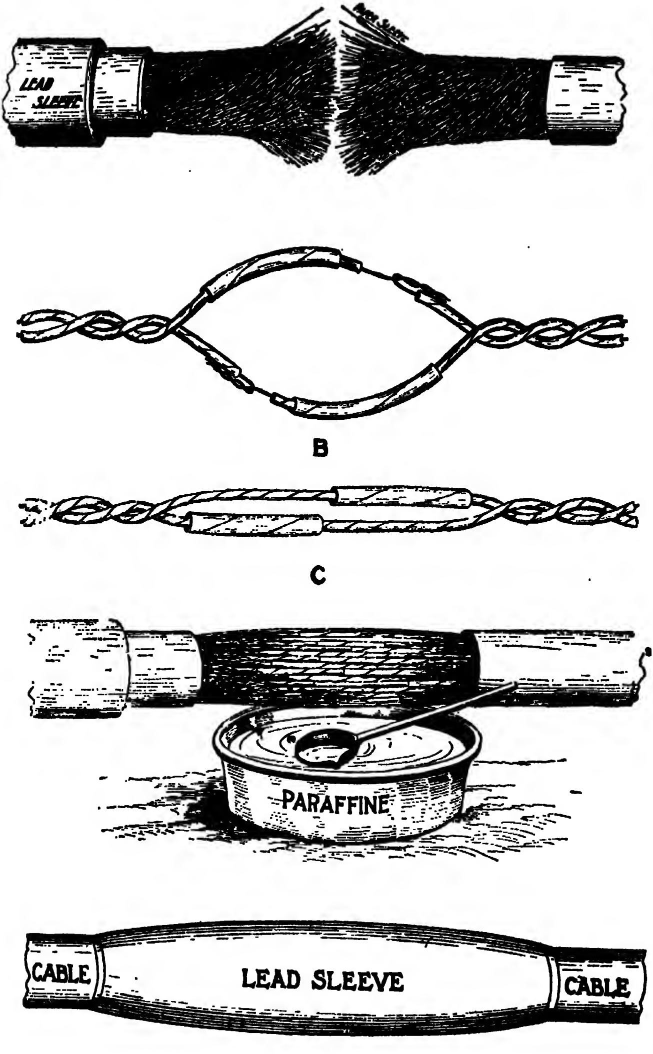


FIG. 97.—Different Stages in the Splicing of a Telephone Cable.

untwisting and exposing the wires to moisture. The lead sleeve should then be slipped over one of the cable ends, and about 1¼ inches of the insulation on each conductor removed, the wires to be joined together being given the proper lengths so that the different splices will not be bunched together at one place, but evenly distributed over the 24 inches between sheaths. A paper sleeve is then slipped over one of every two conductors to be joined, as shown at *A*, Fig. 97, and after the wires of each pair in one cable are joined to those of each pair in the other cable, the twisted conductors are turned down as at *B*, the paper sleeves slipped over the joints as at *C*, and by means of the ladle hot paraffin is poured over the joints as at *D* until no bubbles appear in the hot liquid. The bunch of conductors is then wrapped with cotton serving, the lead pipe is placed with its center over that of the splice, and its ends which project over the two cable sheaths are hammered down and soldered to them, as at *E*, while the splice is still hot. The best flux for this soldering is the grease from a tallow candle.

TESTING TELEPHONE LINE WIRES AND CABLES

Continuity Tests, for determining whether or not a line wire or cable wire is broken, are made by grounding the wire at one end of the line and with a 3-cell battery and buzzer in series and grounded at the other end, touching the remaining terminal to the wire undergoing test. If the buzzer operates, the wire is continuous; if the buzzer fails to work, the wire is broken.

Testing for Crosses between wires or between wires and cable sheath is done by means of a 3-cell battery and telephone receiver. Taking, for example, the case of a cable still upon its reel, the connections are made as in Fig. 98. *N* represents the near end and *F* the far end of the wire being tested, *B* the battery, and *T* a telephone receiver. All the wires of the cable at *F* are carefully separated from each other and from the lead sheath; those at *N* are stripped of their insulation except the one under test, and are connected together and to the lead sheath by the wire *C* leading to the battery. The tester rapidly taps the free binding post of the receiver with the conductor joined to

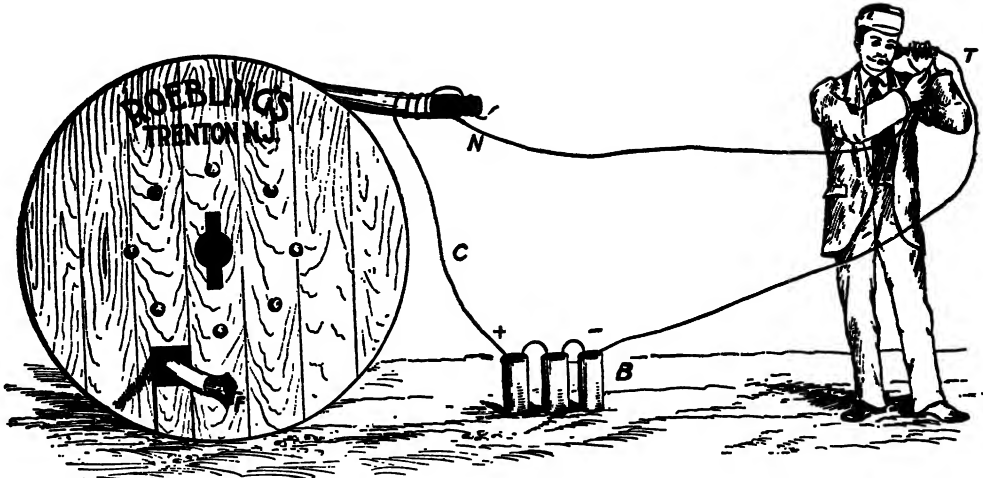


FIG. 98.—Method of Testing a Telephone Cable for Crosses

the wire undergoing test. The first tap, and perhaps the second, will produce a distinct click in the receiver, but if the wire tested is perfectly insulated no further sound in the receiver will follow the tapping. If, however, the wire is crossed with any other wire in the cable or with the sheath, every tap will be followed by a distinct click in the receiver. A partial connection caused by

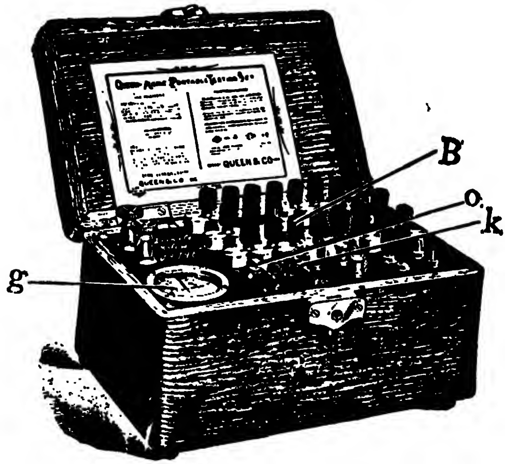


FIG. 99.—A Portable Wheatstone-Bridge Testing Set

moisture in the paper insulation will be indicated by faint clicks. In the same manner other wires in the cable may be tested, care always being taken to see that the exposed ends of the wires at *F* are separate from each other and from the sheath.

Locating Grounds, Crosses, or Swinging Wires can conveniently be done by means of a portable

Wheatstone-bridge testing set, Fig. 99, connected as shown in Fig. 100. The troublesome line wire is denoted by *m*, Fig. 100; one end of this wire is connected to the Wheatstone bridge *B* at *d*, and its other end is connected to *h* either directly or by

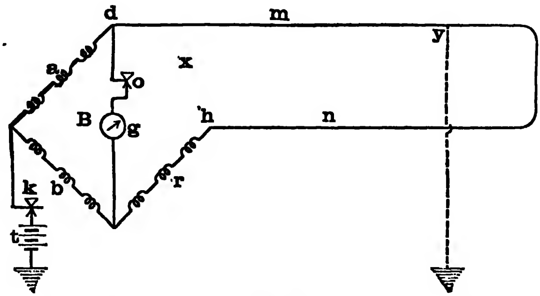


FIG. 100.—Connections for Locating Grounds, Crosses, or Swinging Wires

means of a perfect conductor *n* of the same resistance per unit length as *m*. The point *y* represents the location of the trouble, which we will suppose to be a leakage to ground. The ratio arms of the bridge are denoted by *a* and *b*, the adjustable resistance arm by *r*; and the circuit *d m n h*, consisting of the defective wire *m* and the perfect wire *n*, forms the resistance *x*. The junction of *a* and *b* is connected to ground through the key *k* and battery *t*. By introducing equal resistances in the *r*-arm, a balance is finally obtained; this is indicated by no deflection in the galvanometer *g* when the keys *k* and *o* are closed. Knowing the value of *x* from the size and length of the wires *m* and *n*, the resistance of the wire length *h y* can be found

by substituting the values of x and r in the formula $h\,y=\frac{x-r}{2}$. Dividing the value thus found for $h\,y$ by the resistance per foot or mile of the wire gives the distance of the fault from h in feet or miles. The portable testing set, Fig. 99, contains, in addition to the Wheatstone bridge B, the galvanometer g, the battery, and the keys o and k as indicated.

For locating crossed or swinging conductors, one of the defective wires must be grounded, and the other joined by means of a perfect wire to the points d and h of the bridge as in the previous case. This test is also conducted like the preceding one. If the crossed or swinging conductors make good contact with each other, the location of the cross can be found by measuring the resistance of the circuit thus formed (it being equal to $\frac{a}{b}\,r$), and dividing the result thus obtained by twice their resistance per unit length. For this test the battery t and key k are connected from the junction of a and b, Fig. 100, to h instead of to ground. The values of a and b in this case may be made respectively 10 ohms and 100 ohms, for greater accuracy.

Testing Out the Separate Pairs of a Cable requires two men, one at each end of the cable, provided with a battery, electric bell or buzzer, and a portable telephone set. A wire at one end

of the cable is first connected through the buzzer to ground. At the other end of the cable the battery and buzzer are joined in series, and one terminal of the connection is grounded while the other terminal is scraped over the bared conductors. When contact is made with the conductor previously grounded at the further end of the cable, both buzzers will operate. This con-

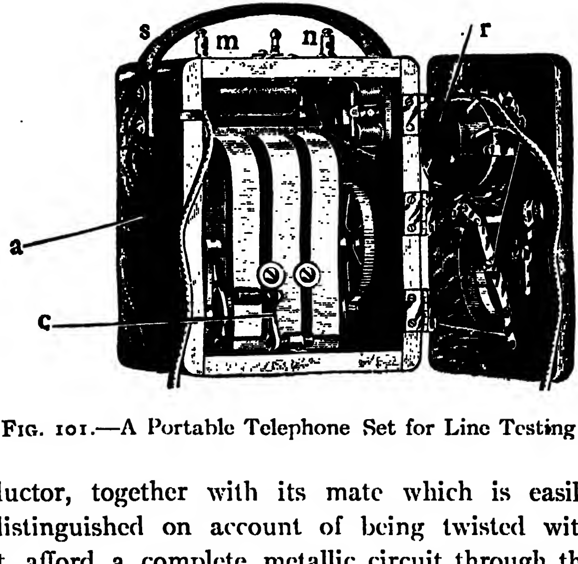


FIG. 101.—A Portable Telephone Set for Line Testing

ductor, together with its mate which is easily distinguished on account of being twisted with it, afford a complete metallic circuit through the cable. If the portable telephone sets be now connected to this circuit and the test continued as before, the separate pairs can be tested and numbered with but little trouble.

An Acme telephone set adaptable for line testing is shown in Fig. 101. The working parts are

completely inclosed within the box *a* when not in use, even the receiver *r* and the crank *c* of the magneto generator being thus housed. By means of the strap *s* the set can easily be carried from place to place, connection being made to the line at the binding posts *m* and *n*.

WIRING AND OPERATION OF SPECIAL TELEPHONE SYSTEMS

Party-Line Systems.—In these, two or more telephone stations are connected to one line, and where a central office or exchange is provided, the line is connected to one set of switchboard terminals. If there is no exchange the system is operated by the parties who use it. Party-lines have been devised to reduce cost of installation and operation over that necessary when each telephone station is connected to a separate line circuit. They may be divided into series party-line systems and bridging party-line systems. Although the regular wiring for both these cases has already been illustrated and described under *Series Connections* and *Bridging Connections* of telephone instruments, there are several modifications of these which have proved adequate in meeting special requirements and merit consideration here. Details regarding size of wire, etc., follow the instructions previously given.

Series Party-Line Systems.—The simplest of

these systems is shown in Fig. 102. Magnet telephones are used for transmitting instead of the usual carbon transmitters, and batteries are employed instead of magneto generators. In each of the 3 stations shown, *t* represents the trans-

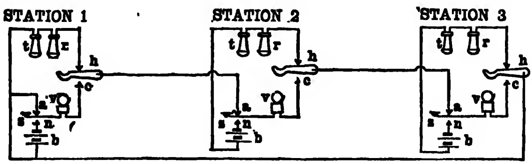


FIG. 102.—The Simplest Form of Series Party-Line System

mitter, *r* the receiver, *h* the hook switch, *b* the battery, *v* the battery bell or buzzer, and *s* a switch. When a station is not in use the receiver hangs on the hook switch, causing the latter to connect the line with the lower contact *c*, and as the switch *s* is normally held against the upper contact *a* by a spring, the bell circuit is closed. When a signal is to be sent, the receiver is removed from the hook switch and the switch *s* pressed down upon the lower contact *n;* the current from the battery in that station then rings the bells in the other stations and, according to the number of rings, signals the desired party. Conversation is then carried on as usual, one of the magnet telephones being used as the transmitter and the other as the receiver. The extreme simplicity of this arrangement is accompanied by little cost and trouble for apparatus and wiring, but the system is

practicable only over distances of a few hundred feet.

Carbon Transmitters Without Induction Coils can be used in series party-line systems as shown in Fig. 103. The same lettering is employed as in Fig. 102 for corresponding parts, so the different apparatus will be easily recognized. It will be noted an extra battery *x* serves in the two end stations for operating the transmitters. This system like the preceding one is practicable only over short distances. It is convenient in that it does not require the use of induction coils and magneto generators.

Ringing Current Supplied by Battery which furnishes the talking current, instead of by a magneto generator, is a feature of some series party-line systems. The wiring for a three-party-line system of this kind is shown in Fig. 104. Each station is

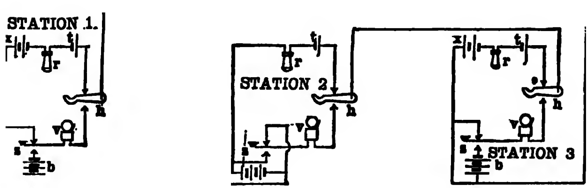


FIG. 103.—Series Party-Line System Using Carbon Transmitters without Induction Coils

wired the same, and when not in use the receiver hook *h* is down and the switch *s* is up, leaving the battery bells in circuit. In systems where battery bells are used in series, of which the present one is an example, the vibrations must be short-cir-

cuited in all bells but one. When a signal is to be sent, the switch *s* is pressed down, the receiver being left on the hook, and the battery at that station causes all the bells to ring. Upon removing the receiver from the hook switch, the latter flies up, connecting the same battery in series with

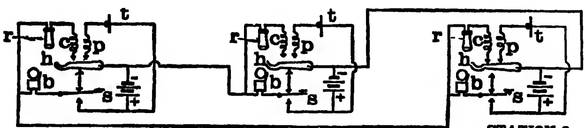


FIG. 104.—Series Party-Line System in which Both Ringing Current and Talking Current are Obtained from One Battery at Each Station

the transmitter *t* and primary winding *p* of the induction coil as in Station 3. The secondary winding *c* of the induction coil and the receiver *r* are then in connection with the line as shown, while the switch *s* and bell *b* are disconnected. It is obvious that in this system the talking current must flow through the bells of those stations not in use in order to reach its destination. The batteries should be connected as indicated, so that in case two or more signaling switches are depressed simultaneously, the batteries will agree in polarity.

Bridging Party-Line Systems.—These systems when wired other than according to the regular *Bridging Connections* previously given are arranged for selective signaling. By "selective signaling" is meant that the bell in any one station of a party-

line system can be rung without ringing the others. Bridging party-line systems thus fitted are generally connected to a central office or exchange where a switchboard and operator are provided to connect the station of the party signaling with the station of the party desired; in other words, systems of this kind are used where the number of stations and their importance are such as to warrant a comparatively high grade of service.

A Two-Party-Line Selective System wired on the bridging plan is shown in Fig. 105. Suppose a party on some other circuit entering the exchange has signaled the operator that he desires a connection with Station 1 shown in the diagram. The operator first pushes her master-key to the left so that it makes contact with the left-hand stop. When the plug is inserted in the jack connected to the desired line and the ringing key is closed, current from the magneto generator will pass out on the "sleeve" side of the line down through binding post 5 in Station 1, through its magneto bell, and by binding post *G* to ground and back to the grounded generator in the exchange. This current will ring the bell in Station 1 because this bell is connected between 5 and *G;* it will not, however, ring the bell in Station 2 although the bell there is similarly connected between 5 and *G*, because the binding post 5 is joined to the "tip" side of the line instead of the "sleeve" side.

If the operator be requested to signal Station

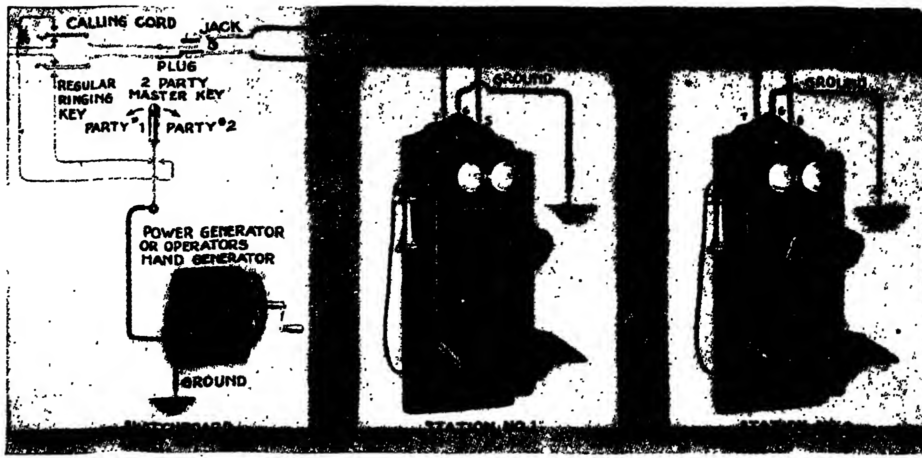


FIG. 105.—Bridging Two-Party-Line System Arranged for Selective Signaling

2 she would push the master-key to the right-hand contact and proceed as before, whereupon the ringing current would pass out on the "tip" side of the line and ring the bell in Station 2. The bell in Station 1 would not be affected for the reason previously given. Having raised the desired party the operator would connect the switchboard terminals of his line circuit with those of the calling party, thereby enabling them to converse with each other. By means of a low-resistance magnet drop connected across the line at the switchboard and cut out of circuit when the plug is inserted in the jack, either of the parties at Stations 1 or 2 can signal the operator with the bridging magneto generator in their telephone set without disturbing the other. The bells at the stations are wound to a resistance of 1,000 ohms.

The principle of the selective system just described can advantageously be employed when there are any number of parties connected to a line. By having one-half of them connected with their bells between the "tip" side of the line and ground, and the remainder with their bells between the "sleeve" side of the line and ground, only half of the parties connected, instead of all of them, will be disturbed when signaled.

A Four-Party-Line Selective System wired on the bridging plan is shown in Fig. 106. This is a further development of the system in Fig. 105, employing positive and negative pulsating current to actu-

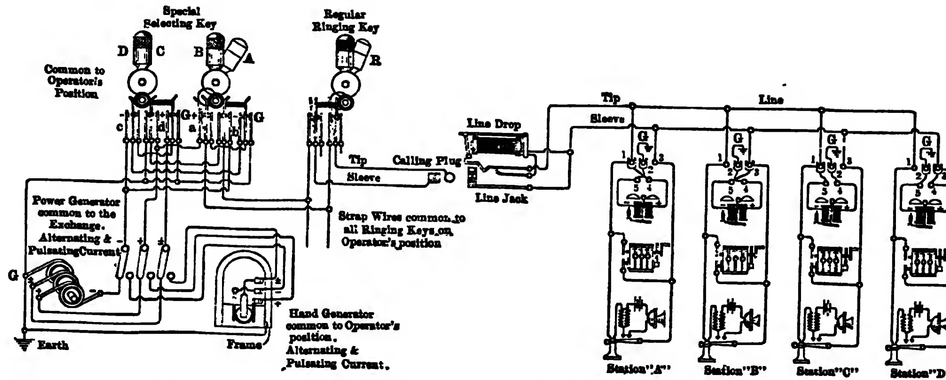


FIG. 106.—Exchange and Station Wiring in a Bridging Four-Party-Line System Arranged for Selective Signaling

ate bells of similar and opposite polarity. Each bell is wound to a resistance of 2,500 ohms and is fitted with a biased spring to hold the armature against one of the pole faces, thus making it sensitive to one polarity of current, but not to current of the opposite polarity, the wrong polarity simply causing the armature to be attracted in the same direction as that produced by the tension of the biased spring. This feature, together with the connections of alternate bells to the "tip" and "sleeve" sides of the line as in Fig. 105, enables any one of the 4 stations, *A*, *B*, *C*, and *D*, Fig. 106, to be signaled without ringing the bells in the remaining stations. The terminals of each telephone set are joined to the lines wires and ground in the same manner, but the leads from the bells to the terminals are connected differently as shown, to bring about the results described. The line wires terminate at the exchange switchboard in a low-resistance magnet drop, as in the preceding case, so that a party signaling the exchange does so without ringing the bells in the telephone sets.

The wiring in the exchange for a party-line circuit of this kind is shown at the left of Fig. 106, and includes, besides that for the line drop, jack, and plug, the connections of the generators giving the positive and negative pulsating current, in addition to the alternating current used for regular ringing, and of the generator switch, special selecting key, and regular ringing key. In calling

a party the operator first sets the special selecting key to correspond to the station desired, pressing it perhaps as indicated by the dotted lines so as to make contact between the proper springs; after inserting the calling plug in the line jack, she depresses the regular ringing key into its dotted position, thereby allowing the ringing current to flow through the signaling circuit. When the special selecting key is in its upright or normal position, alternating current is available, but when pressed to the right or left, places positive or negative pulsating current at the disposal of the operator.

Intercommunicating Systems.—In these, 3 or more, usually not over 15, stations in the same or adjacent buildings are connected together, so that a party at one of them can call up and converse with a party at any other without the use of an exchange switchboard and operator, but with mere privacy and as satisfactory selective signaling as supplied by the best of such systems; also at a comparatively small cost of operation. At each station there must be at least one wire to every other station and a common return wire which runs through all the stations. If battery bells and one common ringing battery are used, there must be at least two more wires than there are stations. No. 18 B. & S. gage rubber-covered copper wires are preferably used; for connecting the stations together these wires may be formed into a cable, if desired, and covered with friction tape.

A Common Form of intercommunicating system is shown in Fig. 107. Four stations, 1, 2, 3, and 4, each fitted with series polarized bells, magneto generators, and the usual talking instruments, are there indicated connected together by the four wires 1, 2, 3, and 4 and the common return wire *r*. At each station there is a switch *s*, the contact points of which are joined to the wires connecting the stations. With the contact arm of each switch on the contact point corresponding to its station, a party at any station can signal any other station by moving his switch arm to the contact point corresponding to the station desired and turning his generator handle; this action will ring the bells only at the station called and the station calling, and the talking current will likewise pass only through these two stations. In the diagram the switch at Station 1 is set for signaling Station 4. Each of the telephone sets in this system has the same interior wiring, and the number of wires between the stations is one in excess of the number of stations connected. Although only four stations are shown in Fig. 107, any number desired may be connected by developing the plan along the lines indicated. In order that an instrument in this system be in circuit for receiving a call it is necessary that its switch arm be on the contact point corresponding to its own station; this necessitates that each party after making a call returns the switch arm to its original position after his conversation is finished.

An Improved Form of intercommunicating system is that in which a station can be called even

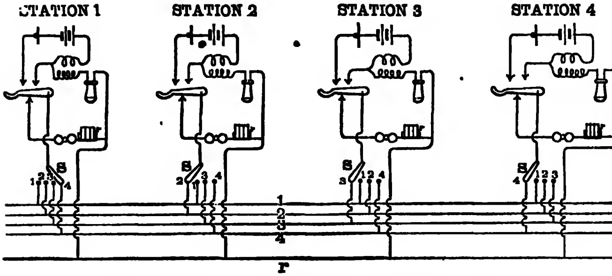


FIG. 107.—Intercommunicating System Fitted with Magneto Generators and Polarized Bells

though its switch arm is not on the proper contact point; the wiring for such a system is shown in Fig. 108. The telephone sets contain the same

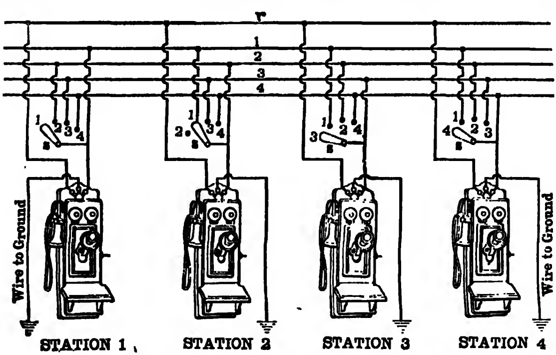


FIG. 108.—Method of Wiring an Intercommunicating System so that a Station can be Called Regardless of the Position of Its Contact Arm

apparatus as in the preceding case, connected up in the same way. One terminal of each set, however,

is wired both to the switch arm *s* and to the connecting wire corresponding to that station, while the remaining terminal is joined to the common return wire *r*. Each station has its contact point mounted at the extreme left of the row, but is not connected in circuit; this point is intended to be covered by the switch arm after a conversation is finished, but as will be seen by referring to the diagram a station can be called while its switch arm is on any of the contact points. In Fig. 108 the switch at Station 2 is set for signaling Station 1. Supposing this switch was left in the position shown, Station 2 could be signaled by any one of the other stations; if, however, either Station 3 or 4 signaled Station 1, the bells in both Stations 1 and 2 would ring. Although this would be somewhat annoying to the party in Station 2, it would, nevertheless, be due to his own carelessness in not having his switch arm in its proper position.

A Battery and Battery Bells can be used in place of magneto generators and bells on intercommunicating systems if wired as in Fig. 109. The connections shown permit any station to signal any other station regardless of the position in which the switch arm at the station called has been left. Although but 3 stations are shown, any number of them can be connected, the number of connecting wires required being 2 in excess of the number of stations. Each station contains the same apparatus wired in the same manner, the transmitter battery *b* being retained as in the preceding cases.

The signaling battery *t* serves for the entire system and is connected between the battery wire *a* and the common return wire *c* at any convenient part of the system. The battery bell *e* at each station is permanently connected to the contact point corresponding to its station, and the pivot of the switch arm *s* is wired to the push switch *k* in each case. The connections shown enable only the bell at the station called to ring; the bell in the calling station not being in circuit will not ring.

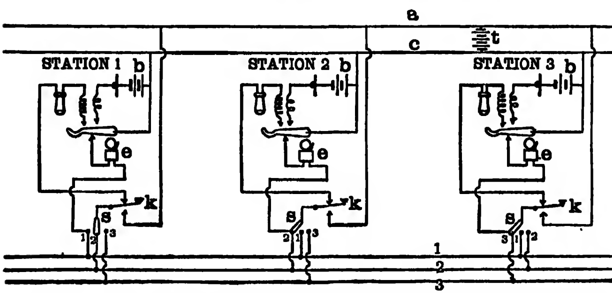


FIG. 109.—Wiring for an Intercommunicating System Using a Common Signaling Battery in Place of Magneto Generators

Although it is usually advisable to have both these bells operate in order that the party signaling may know his signal has been transmitted, it is not practicable to do so in this case.

An Exchange Communicating System can be had by wiring the stations as in Fig. 110. The central or exchange Station C is the only one that can be signaled from the other stations, but from this station any of the others can be signaled. The wires *m* and *n* connect with each of the sta-

tions as shown, and from C there is a wire *w* to each of the other stations. A party at Station *A* or *B* signals Station C by closing the switch *s*; this closes the circuit containing the battery *b* and battery bell *t* in Station C and raises the party there. From Station C either of the other stations can be signaled independently by placing the switch arm *v* on the contact point corresponding to the station desired and closing the switch *e*.

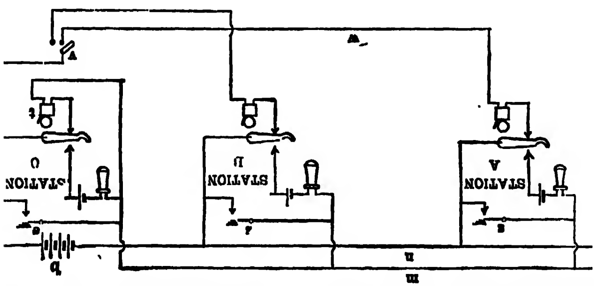


FIG. 110.—Connections for an Exchange Communicating System

Station C can be signaled regardless of the position in which the switch arm *v* is left. It will be noted that no induction coils are used in this system and that the battery *b* in Station C furnishes current for both signaling and talking purposes.

Automatic Intercommunicating Systems are those in which the switch arm at each station is returned automatically to its normal calling position after a conversation is finished. The Ness system controlled by the Holtzer-Cabot Company is of this kind, and a telephone wall set fitted with

this automatic attachment is shown in Fig. 111; it can be connected to operate according to any of the intercommunicating methods previously described. The party using it moves the switch arm *s* to the contact point corresponding to the station desired, and when through returns the receiver

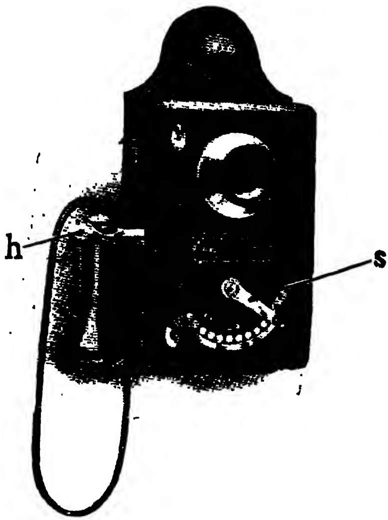


FIG. 111.—Wall Set Fitted with Automatic Intercommunicating Attachment

to the hook switch *h*. The motion of the hook switch when the receiver is hung upon it actuates the mechanism for restoring the switch arm to its normal calling position shown in Fig. 111.

This mechanism, Fig. 112, consists of a dog *d*, pivoted on the short arm of the hook switch *h*, which projects into a notch on a pawl *p* and lifts

the latter out of engagement with a ratchet wheel *w* when the switch hook is pulled down. The ratchet wheel *w* and the contact arm *s* being mounted on the same shaft with a spiral spring, the action just noted permits the spring to return

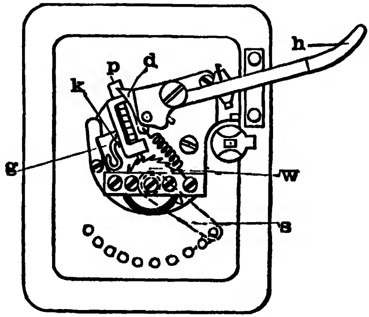


FIG. 112.—Details of the Automatic Attachment in the Wall Set Shown in Fig. 111

the contact arm to its normal position. After the pawl *p* has been raised to a certain point, the dog slips out of the notch on it, permitting the pawl again to come in contact with the ratchet wheel *w* and be ready for the next use of the telephone. To prevent the pawl from engaging with the ratchet wheel before the contact arm *s* has reached its final position, the second dog *g* is provided; this is pressed by a spring so as to project under the pin *k*, carried on the pawl *p*, and holds *p* away from the ratchet wheel until *s* has traveled to its normal position. Then a cam on the ratchet wheel forces the dog *g* away from the pin *k* and allows the pawl to drop into position.

The Private Branch Exchange.—This is a small central office differing from the main telephone exchange only in being smaller. It is intended to relieve the latter from calls not extending outside the building in which it is located, and to effect a saving in the amount of wire required for an installation. Instead of each station in a building being connected with the main telephone exchange, it would in the present case be onnected with the private branch switchboard, and those calls not extending outside the building would be handled on this board entirely irrespective of the main exchange. By means of a few trunk lines running from the branch switchboard to the main switchboard, calls to parties outside the building can be put through by operators stationed at these boards. The use of a few trunk lines and short connecting wires to the different telephone sets, instead of individual wires extending the entire distance between the telephones and the main exchange, effects a considerable saving in copper. This kind of installation is especially adapted and widely used in office buildings, hotels, and factories. Owing to the similarity between a private branch exchange and a small central exchange such as will next be considered, no separate description and discussion of the former will be necessary.

A Small Central Exchange.—By a small central exchange is here meant one whose capacity does not exceed 200 stations. The line conductors leading into such an exchange may be either open

wires or cables, and as a rule complete metallic circuits must be provided for.

Protection to the exchange apparatus is usually similar to that afforded the telephone set in the user's premises. This, it will be remembered, comprises a fuse, a heat coil, and a carbon lightning arrester for each side of the line. A terminal head like that shown in Fig. 95, but fitted with fuses for each line wire serves well for protection from abnormal currents if utilized on the last pole of the line, while on the main distributing board in the exchange may be mounted the carbon lightning arresters and the heat coils for intercepting sneak currents. The main distributing board's chief function, however, is to provide fixed terminals for the line conductors and fixed terminals for the wires running to the exchange switchboard, so that these two sections of wiring will be entirely independent of each other and either one can be changed without necessitating a change in the other. It is then possible to shift any outside circuit to any switchboard circuit by simply changing the "jumper" wires connecting them together.

To facilitate this work, the terminals are numbered as in the distributing board shown in Fig. 113. In the case of open wire lines the terminals are numbered to correspond to the insulator pins carrying the conductors connected to the terminals. The pins in a complete metallic installation are numbered as follows: standing with the back to the exchange and facing the direction of the

pole line, the two points at the extreme left of the top cross-arm are each No. 1, the next two pins No. 2, and so on toward the right, continuing with the left-hand pins on the second cross-arm in the same manner. The distribution board, Fig. 113, is of hard wood, fitted with fuses *s* and carbon lightning arresters *a*, but carries no heat coils. It is, however, fitted at *c* for plug tests whereby grounds, short circuits, crossed wires and open lines may be determined. A testing wire is readily plugged in on any circuit as shown at *n*. The board is mounted on the wall or any flat surface near the switchboard, and is connected with the switchboard

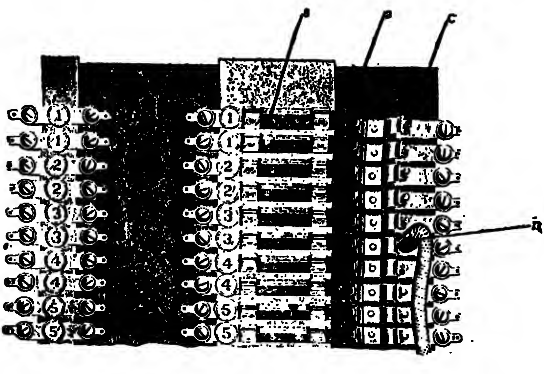


FIG. 113.—Distributing Board Fitted with Protective Apparatus and Test Plugs

apparatus by No. 22 B. & S. gage copper wires, tinned and formed into cables of 26 pairs each. The wires are each covered with a layer of silk and a layer of cotton thread placed one above the other. The cotton thread on one conductor

of a pair is white and on its mate is colored, so as to distinguish the one from the other. After being paraffined, the insulated conductors are bound

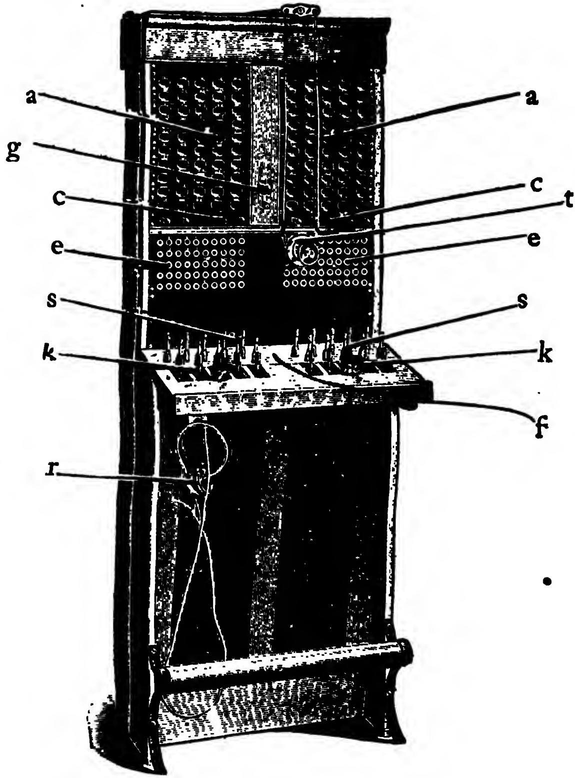


FIG. 114.—Telephone Switchboard for a Small Exchange

together with cotton braid saturated in powdered soapstone and painted to exclude moisture.

The Exchange Switchboard for 100-line circuits or stations is shown in Fig. 114. It consists of

the following parts: the line drops *a a*, 1 for each line circuit, by means of which the switchboard operator is signaled; the clearing-out drops *c c*, 1 for each of the 10 operator's circuits provided, by means of which the operator is notified when a conversation between two parties connected through the board is finished; the spring jacks *e e*, which are numbered to correspond to the line drops to which they are wired and are connected one to each line circuit; the plugs *s s*, which, being the terminals of the operator's 10 circuits, are therefore 20 in number and which when inserted in the jacks connect together the line circuits wired to them; the ringing and listening keys *k k*, 1 for each of the operator's 10 circuits, and which when depressed forward connect the magneto generator at *g* with the station plugged, for signaling the party there, and when depressed backward connect the operator's receiver *r* in circuit for enabling her to determine from the signaling party the station desired and to listen in on the conversation and learn if the proper parties are connected; and the operator's transmitter *t*, which is adjustable as to height, for enabling the operator to speak with the parties connected, when necessary. Telephone switchboards up to 200 stations capacity are built along the same lines as the one in Fig. 114.

Each Line Circuit terminates in the switchboard as shown in Fig. 115, *l* and *l* being the line wires, *d* the distributing board, *S* the spring jack, and *A* the line drop. One side of the line circuit is

connected directly with the brass strip *r* of the spring jack, which terminates in a curved end. The other side of the line circuit is joined to the brass spring *b*, the end of which is also curved as shown. The spring *b* has a contact point which, when in its normal position, presses against the spring *g*, and *r* is similarly connected to the spring *f*. The line drop *A* is joined in circuit by wires connecting its magnet winding to the springs *f* and *g*.

A party desiring a connection with some other party signals the switchboard operator at the cen-

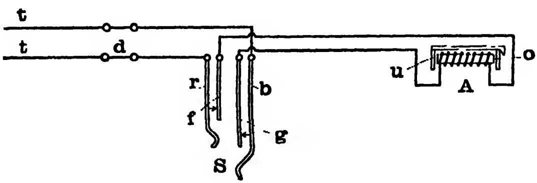


FIG. 115.—Each Line Circuit Terminates in the Exchange Switchboard as here Shown

tral exchange by operating his magneto generator; this sends a current through the magnet winding of the line drop *A* connected to his circuit at the switchboard, and, by attracting the armature *u*, releases a catch which permits the shutter *o* to drop. The swinging down of the shutter attracts the operator's attention and reveals to her the number of the calling party previously hidden by the shutter.

The Operator's Circuit on the switchboard is shown in Fig. 116. The two plugs *m n* and *r v* have their tips *m* and *r* electrically connected to the respective springs *s* and *i* of the ringing keys *R* and

R′, and their sleeves *n* and *v*, which are insulated from their tips, are connected respectively to the springs *e* and *c*. The inner contacts of the springs of one ringing key are connected to the inner contacts of the springs of the other ringing key, and between the wires leading from the outer contacts of both keys is connected the magneto generator *g*. At the points *d* and *h*, in the circuit joining

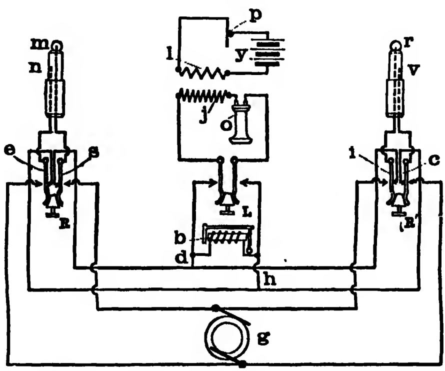


FIG. 116.—Wiring of the Operator's Circuit on an Exchange Switchboard

the ringing keys, wires run to the outer contacts of the key *L*, called the operator's listening key, and between these wires is the clearing-out drop *b*. The springs of the key *L* are connected with the operator's receiver *o* and secondary winding *j* of an induction coil, the primary winding *l* of which is in circuit with the battery *y* and operator's transmitter *p*. In the switchboard there is but 1 primary circuit *l y p*, 1 secondary circuit *o j*, and 1 magneto generator *g*, but the rest of the appara-

tus and wiring in Fig. 116 is repeated for each operator's circuit; in the switchboard, Fig. 114, there are, as previously noted, 10 operator's circuits, enabling 20 different parties to be connected in pairs simultaneously.

A party having signaled the operator as already described, the first duty of the operator is to find from him the number of the party desired. This the operator does by inserting the plug *m n*, called the answering plug, into the calling party's jack *S*, Fig. 115. As all the jacks and line drops are numbered, those connected to the party's telephone bearing the same number as his line circuit and telephone set, it is an easy matter for the operator to select the proper jack in which to insert her plug. When inserted and pushed in, the tip *m* of the plug makes contact with the curved part of the spring *r*, and the sleeve *n* makes contact with the curved part of the spring *b*. As the springs *r* and *b* are forced outward by the plug they separate from the springs *f* and *g* and thus cut out of circuit the line drop *A*. The operator next closes her listening key *L*, Fig. 116, so that its springs touch the outer contacts; this brings her telephone in circuit with the calling party's line and enables her to learn from him the number of the party with whom he desires to speak.

Having been informed of the desired number, the operator introduces her plug *r v*, called the answering plug, into the jack containing the number asked for, and closes the ringing key *R'*.

When this key is closed and the magneto generator g put into operation, current from the generator passes over the line and rings the bell in the desired party's telephone set, attracting his attention. No current will flow elsewhere because the inner contacts of the ringing key R' are opened when this key is closed. The party signaled, upon answering, finds himself in connection with the party who desires to talk with him. As soon as the conversation has been started, the operator opens her listening key L so as to leave her telephone circuit free for answering other calls. When the parties connected have finished their conversation, they hang up their receivers and give the handles of their magneto generators a few turns; this generates the current required to actuate the clearing-out drop b, which, when its shutter falls, acts as a signal to the operator that the parties have finished talking. When the operator receives this "ring off" signal, she withdraws the plugs m n and r v from the jacks in which they were placed.

In the diagram, Fig. 116, it will be noted two ringing keys R and R' are indicated, but that only R' was used in the foregoing procedure. The ringing key R is needed only when the plug m n is used as the answering plug and r v as the calling plug, instead of *vice versa*. As it is not convenient always to use the same plug for the same purpose, the ringing key R is often dispensed with and the listening key L and the ringing key R' combined into one as in the switchboard, Fig. 114.

A Combination Ringing and Listening Key as made by the International Telephone Manufacturing Company is shown in Fig. 117. The handle *h* is all that projects above the switchboard shelf *s*, the springs, etc., being mounted below. The one set of springs form the ringing contacts, and the other set the listening contacts. Pressing the handle forward or backward closes the one set

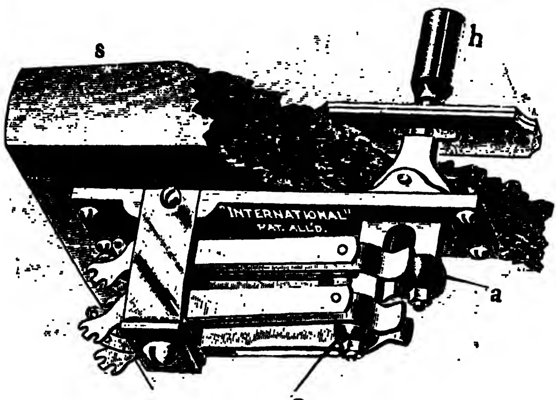


FIG. 117.—Combination Ringing and Listening Key

of springs or the other by reason of the insulated knob *a* or *c* forcing them together on each side.

Spring Jacks and Plugs as made by the Central Electric Company are shown respectively in Figs. 118 and 119. It is readily seen that, when the tip *m* of the plug is inserted through the hole in the part *n* of the jack and comes in contact with the spring *r*, how the sleeve *s* of the plug comes in contact with the spring *b*; how, when the plug is

inserted, the springs *r* and *b* break contact with the springs *f* and *g;* how the two contact parts of the plug are insulated from each other by the

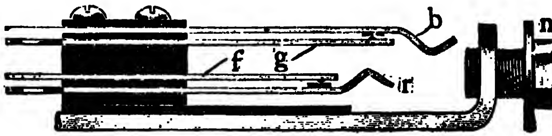


FIG. 118.—A Spring Jack

hard rubber at *z* and connected in circuit by the braided twin conductor cable *l;* and how by screwing the part *n* in or out of the jack it can be adjusted

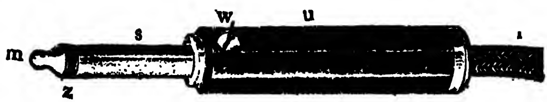


FIG. 119.—Answering or Calling Plug

to act as a stop for the plug so that the plug will make the proper connections when pushed in as far as it will go.

Fig. 120 shows the interior construction of the

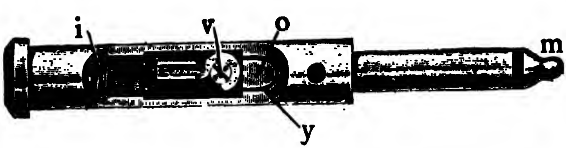


FIG. 120.—The Inner Construction of an Answering or Calling Plug

plug. The protecting fiber cylinder *u*, Fig. 119, has been removed by taking out the screw *w*. The threads at *i* are for holding the cable in the plug

and thus relieving the strain on the conductors, by being screwed into the braid. One of the cable conductors is screwed directly to the outer brass cylinder and is therefore in electrical connection with the sleeve of the plug; the other conductor is fastened by means of the screw *v* to the inner part *o* of the plug, which is entirely insulated from the outer brass cylinder by hard rubber *y* and extends through the sleeve, terminating in the tip *m*.

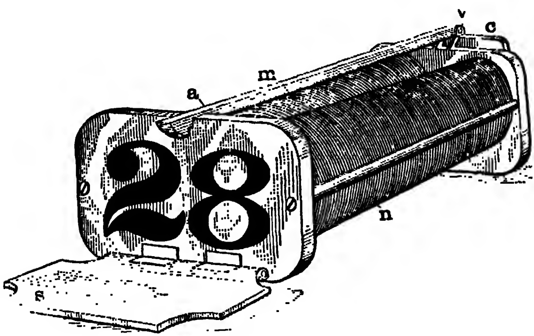


FIG. 121.—A Line Drop

Line Drops and clearing-out drops are not constructed alike. The former, being cut out when the operator introduces her plug, is not in circuit when the line is in use, and may therefore be wound to a comparatively low resistance. A line drop has 2 magnet cores, the windings on which have a total resistance of about 80 ohms, are wound in opposite directions on the 2 cores, and are connected in series. One of these line drops is shown in Fig. 121. When current passes through the

magnet coils *m* and *n*, the armature *c* is attracted and raises the catch *a* attached to it, both *c* and *a* being in one piece pivoted at *v*. This upward movement of *a* releases the shutter *s*, which swings down, exposing the calling party's number.

Unless the switchboard is equipped with self-restoring drops, the operator will be obliged to replace the shutter by hand after it has fallen. With self-restoring drops, however, the act of introducing the plug into the jack mechanically restores the shutter. In this case the drops and

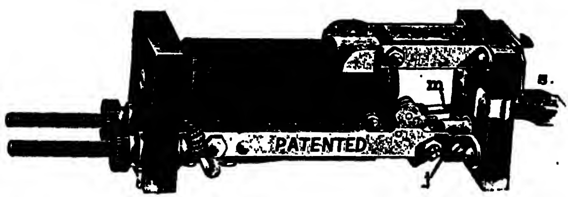


FIG. 122.—Self-Restoring Drop

jacks are mounted together, each jack beneath its corresponding drop, as in the Central Electric self-restoring drop, Fig. 122. When the plug is inserted in the jack *j*, the lever at *m* is actuated and mechanically restores the shutter *s* to its normal position.

The Clearing-Out Drops are in circuit whenever the lines across which they are wired are in use. In order that no more current than necessary flows through the magnet coil of the clearing-out drop, this coil is wound to a high resistance, about 500 ohms. Unlike the line drop, there is but one

central core and one magnet coil. As the clearing-out drops are mounted side by side, and each of them is connected to a separate circuit several of which may have currents in them at the same time, cross talk is liable to arise owing to the current in

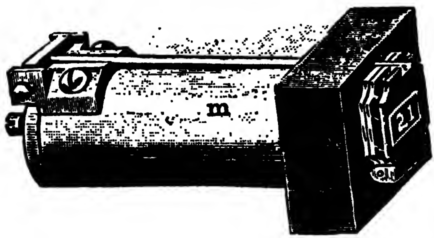


FIG. 123.—Clearing-Out Drop

one drop inducing a current in the adjoining drop. To prevent this, a cylindrical iron shield must inclose the magnet coil as at *m*, Fig. 123: this serves to collect the lines of force within itself and thus prevents them from passing beyond. In other respects the clearing-out drop is constructed similarly to the line drop already described.

The Switchboard Wiring is done chiefly with the No. 22 B. & S. gage copper wires contained in the cables leading from the distributing board. Short lengths of similar cable are also used. The cable from the distributing board is carried up one side of the back of the switchboard, fastened in place by leather straps, and at each row of jacks, commencing at the bottom row, enough wires are bent horizontal and fanned out to connect with each jack in that row, to which they are soldered.

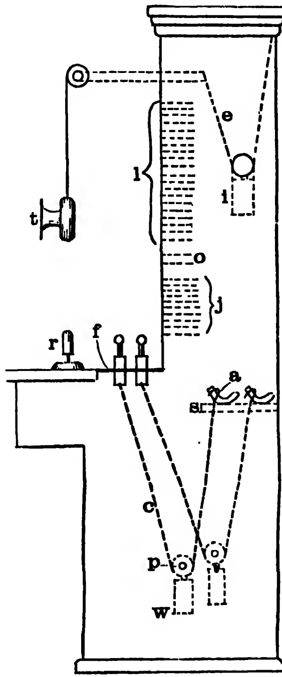
A separate cable is then used in the same manner on the opposite back side of the board to connect the jacks with their corresponding line drops above. A third cable is similarly employed to wire the clearing-out drops to the operator's circuits, and twin conductors join together the operator's transmitter, induction coil, battery, receiver, and listening keys.

Flexible wire cords, each containing a pair of tinsel conductors separately insulated with silk and cotton coverings and bound together with cotton braid as in Fig. 124, which shows an Acme

FIG. 124.—Flexible Switchboard Cord for Wiring the Plugs in Circuit

switchboard cord, connect the plugs in circuit. The cords are held in place below the plug shelf *f*, Fig. 125, by weights *w*, each carrying a pulley *p* around which passes the cord *c*. When the plugs are inserted in the jacks *j* to connect with the different line circuits, the weights on the cords keep the cords taut and thus prevent them from becoming tangled. The connections between the plug cords and the conductors leading to the ringing keys *r* are made on the cord shelf *s*, which extends across the rear of the board somewhat below the level of the plug shelf. Hereon are screwed brass strips *a*, etc., having holes in their ends. In the lower holes at one end are inserted

the plug cords *c*, etc., the ends of which are wrapped with brass wire wound spirally. These are bent around in the form of a hook and returned through the upper holes. The wires from the ringing keys are passed through the holes in the opposite ends of the strips and soldered permanently in place. The operator's transmitter *t* is connected in circuit by the flexible wire cord *e*, which, by aid of the weight *i*, balances the transmitter and enables it to be adjusted as to height. The relative positions of the line drops and clearing-out drops are shown at *l* and *o* respectively.



25.—
of an Exchange Switchboard, Showing the Relative Positions of the Apparatus on It

The Useful Life of the Switchboard is about 20 years. During this time it will require occasional repairs, particularly on the cords and plugs, and perhaps a drop will burn out now and then, necessitating a new one.

Telephone Exchange Service should be supplied under a definite form of contract. This latter

may take the form of a flat-rate contract in which the party supplied agrees to pay a fixed sum per year for unlimited telephone service. Another form is the message-rate contract in which a party agrees to pay for a certain number of messages sent per year. If this number is not reached he is allowed a rebate, but if the number is exceeded he is charged a fixed sum per message in addition to his contract price. Still another form is the pay-station contract often made with shop- and hotel-keepers. In this, a telephone set is installed for public use, and the party in whose place of business it is located is allowed a percentage of all calls above a certain number sent over his line, he collecting from the public the usual charge per call. In message-rate and pay-station contracts the operator at the exchange must keep account of the number of such calls sent in and the stations to be charged with them.

APPENDIX

The Ohm is the unit of resistance, and is equal to the resistance of a column of pure mercury 106.3 centimeters (1 centimeter = 0.3937 inch) in height and 0.01 square centimeter in cross-section.

The Ampere is the unit of current, and is equal to the current which, when passed through a standard solution of nitrate of silver in water, deposits silver at the rate of 0.001118 gram per second (1 gram is the weight of 1 cubic centimeter of water at 39.2° F.).

The Volt is the unit of electromotive force, and is the pressure which will force a current of 1 ampere through a resistance of 1 ohm.

The Watt is the unit of electrical power, and is the amount of power expended in a circuit in which a current of one ampere is maintained by an electromotive force of 1 volt.

The Coulomb is the unit quantity of electricity, and is the quantity transferred by a current of 1 ampere in 1 second.

The Farad is the unit of electrostatic capacity, and is the capacity that will contain 1 coulomb of electricity at a pressure of 1 volt.

The Microfarad is equal to one-millionth of a farad.

The Megohm is equal to 1,000,000 ohms.

Ohm's Law states that the current in amperes flowing through a circuit equals the pressure in volts across the circuit, divided by the resistance of the circuit in ohms. Two important deductions from Ohm's law are: The electromotive force in volts across a circuit equals the current strength in amperes multiplied by the resistance of the circuit in ohms. The resistance of a circuit in ohms equals the electromotive force in volts across it, divided by the current in amperes.

Table of Dimensions of Copper Wire

Gage No. B. & S.*	Diam. Mils**	Area Circular Mils†	Bare Wire			Underwriters' Wire		
			Pounds per 1000 Feet	Pounds per Mile	Feet per Pound	Pounds per 1000 Feet	Pounds per Mile	Feet per Pound
8	128.490	16509.7	49.99	263.96	20.00	69	301	14.5
9	114.430	13094.2	39.65	209.35	25.22			
10	101.890	10381.6	31.44	165.98	31.81	50	264	20.0
11	90.742	8234.11	24.93	131.65	40.11			
12	80.808	6529.94	19.77	104.40	50.58	31	164	32.0
13	71.961	5178.39	15.68	82.792	63.78			
14	64.084	4106.76	12.44	65.658	80.42	22	116	45.0
15	57.068	3256.76	9.86	52.069	101.40			
16	50.820	2582.67	7.82	41.292	127.87	14	74	70.0
17	45.257	2048.20	6.20	32.746	161.24			
18	40.303	1624.33	4.92	25.970	203.31	11	58	90.0
19	35.890	1288.09	3.90	20.594	256.39			
20	31.961	1021.44	3.09	16.331	323.32			
21	28.462	810.09	2.45	12.952	407.67			
22	25.347	642.47	1.95	10.272	514.03			

***B. & S.** is the abbreviation for Brown and Sharp—the name of the standard wire gage in this country.

****A Mil** equals one-thousandth of an inch.

†**A Circular Mil** is the unit of area when considering the cross-section of a wire; it is the area of a circle whose diameter is one mil, and is, therefore, equal to 0.000000785 square inch.

Table of Carrying Capacities and Resistances of Copper Wire

Gage No. B. & S.	Safe Carrying Capacities (Cur. in Amps.)		Resistances at 75° F. (23.9° C.)†			
	Concealed Work *	Open Work **	Ohms per 1000 Feet	Ohms per Mile	Feet per Ohm	Ohms per Pound
8	33	46	.62849	3.31843	1591.1	.0126
9			.79242	4.18400	1262.0	.0200
10	25	32	.99948	5.27726	1000.5	.0317
11			1.2602	6.65357	793.56	.0505
12	17	23	1.5890	8.39001	629.32	.0804
13			2.0037	10.5798	499.06	.128
14	12	16	2.5266	13.3405	395.79	.203
15			3.1860	16.8223	313.87	.323
16	6	8	4.0176	21.2130	248.90	.514
17			5.0660	26.7485	197.39	.817
18	3	5	6.3880	33.7285	156.54	1.299
19			8.0555	42.5329	124.14	2.065
20			10.1584	53.6362	98.44	3.284
21			11.8088	67.6302	78.07	5.222
22			16.1504	85.2743	61.92	8.302

* **Concealed Work** is wiring composed of insulated conductors inclosed in a tube or molding, and not exposed to the air.

** **Open Work** is wiring composed of weatherproof insulated conductors exposed to the air.

† **Resistance of Copper** increased 0.21 per cent. for each degree Fahrenheit increase of temperature.

TABLE OF DIMENSIONS AND RESISTANCES OF GALVANIZED IRON WIRE

Gage No. B. W. G.*	Diameter Mils	Weight in Pounds		Breaking Strength in Pounds		Resistance per Mile in Ohms		
		Per 1000 ft.	Per Mile	Iron	Steel	E.B.B.†	B.B.††	Steel
6	203	109	573	1.719	3.237	8.21	9.6	11.35
7	180	85	450	1.350	2.545	10.44	12.2	14.43
8	165	72	378	1.131	2.138	12.42	14.53	17.18
9	148	58	325	.915	1.720	15.44	18.06	21.35
10	134	47	250	.750	1.410	18.83	22.04	26.04
11	120	38	200	.600	1.131	23.48	27.48	32.47
12	109	31	165	.495	.933	28.46	33.30	39.36
13	95	24	125	.375	.709	37.47	43.85	51.82
14	83	18	96	.288	.541	49.08	57.44	67.88

*B. W. G. is the abbreviation for Birmingham wire gage—an English wire gage differing but slightly from the B. & S. gage.

†E. B. B. is the abbreviation for the "Extra Best Best" grade of iron wire.

††B. B. is the abbreviation for the "Best Best" grade of iron wire.

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